REPORT RESUMES

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CONTROLLING STUDENT RESPONSES DURING VISUAL PRESENTATIONS--STUDIES IN TELEVISED INSTRUCTION, THE ROLE OF VISUALS IN VERBAL LEARNING, REPORT 2.

BY- GROPPER, GEORGE L.
METROPOLITAN PITTSBURGH EDUC. TV STATION, PA.

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THIS IS A REPORT OF TWO STUDIES IN WHICH PRINCIPLES OF PROGRAMED INSTRUCTION WERE ADAPTED FOR VISUAL PRESENTATIONS. SCIENTIFIC DEMONSTRATIONS WERE PREPARED WITH A VISUAL PROGRAM AND A VERBAL PROGRAM ON--(1) ARCHIMEDES' LAW AND (2) FORCE AND PRESSURE. RESULTS SUGGESTED THAT RESPONSES ARE MORE READILY BROUGHT UNDER THE CONTROL OF VISUAL PRESENTATION WHEN STUDENTS RESPOND ACTIVELY THAN WHEN THEY MERELY WATCH PASSIVELY. THESE RESULTS PROVIDED THE BASIS FOR PRACTICAL CONCLUSIONS REGARDING THE TEACHING OF CONCEPTS AND PRINCIPLES BY FILM OR TV LESSONS--(1) PICTORIAL MATERIALS SHOULD BE PROGRAMED TO BE CAPABLE, ON THEIR OWN, OF TEACHING CONCEPTS, (2) DURING SUCH PRESENTATIONS, DISCRIMINATION PRACTICE SHOULD BE BASED ON PICTORIAL RESPONSE OPTIONS, AND (3) PROGRAMED PICTORIAL MATERIALS SHOULD PRECEDE THE ACCOMPANYING VERBAL MATERIALS. OTHER REPORTS IN THIS SERIES HAVE ACCESSION NUMBERS ED 003 211 THROUGH ED 003 213. (JM)

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STUDIES IN TELEVISED INSTRUCTION
the role of visuals in verbal learning

2

CONTROLLING STUDENT RESPONSE DURING VISUAL PRESENTATIONS

George L. Gropper, Principal Investigator

METROPOLITAN PITTSBURGH EDUCATIONAL
TELEVISION STATION and the
AMERICAN INSTITUTES FOR RESEARCH

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STUDIES IN TELEVISED INSTRUCTION
the role of visuals in verbal learning

REPORT 1	A BEHAVIORAL ANALYSIS OF THE ROLE OF VISUALS IN INSTRUCTION
REPORT 2	CONTROLLING STUDENT RESPONSE DURING VISUAL PRESENTATIONS
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CONTROLLING STUDENT RESPONSES DURING VISUAL PRESENTATIONS

Study No. 1: An Investigation of Response Control During Visual Presentations

Study No. 2: Integrating Visual and Verbal Presentations

George L. Gropper, Principal Investigator

METROPOLITAN PITTSBURGH EDUCATIONAL
TELEVISION STATION and the
AMERICAN INSTITUTES FOR RESEARCH

October 1965 - Pittsburgh, Pennsylvania

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FOREWORD

The research on visuals described in this volume was performed under a grant from the U. S. Department of Health, Education, and Welfare, United States Office of Education, grant number 7-48-0000.120, Project 637, under title VII of the National Defense Act of 1958.

The writer is indebted to Dr. Robert Gagné for his review of the entire report and to Mr. Harris Shettel for his review of portions of it.

George L. Gropper
AMERICAN INSTITUTES FOR RESEARCH
October 1965

ABSTRACT

In the belief that learning theory is as applicable to "learning from visuals" as it is to "learning from words," two studies were performed in which principles of programmed instruction were adapted for visual presentations. Science demonstrations were programmed to teach Archimedes' Law in one study and "force and pressure" in the second. In each study, a visual (pictorial) program and a verbal program were prepared. Each of the two programs was designed to be self-contained and, on its own, to teach the concepts required by lesson objectives. The programs were used to investigate these two main issues:

-- how can responses be systematically brought under the control of visual presentations?

-- what are the optimum instructional strategies for use of either visual or verbal presentations and for their potential integration in teaching concepts and principles?

Results of Study No. 1 were as follows:

(1) Students who made active, anticipatory responses to problems posed during the visual demonstration and during the verbal program achieved higher test scores than did students who merely watched the demonstrations passively and merely read printed materials.

(2) On verbal test items, there were no significant differences between students who received either the visual program or the verbal program. On visual test items, however, the visual program group clearly outperformed the verbal program group. Thus, it appears that similarity between learning experience and testing experience is not so crucial for transfer (from learning to testing experience) when the learning experience is visual.

(3) There was a significant interaction between IQ and mode of presentation suggesting that below average students can do better with visual rather than verbal presentations.

(4) Students who first acquired concepts on the basis of the solely visual lesson and then once again (in technical language) on the basis of the verbal lesson achieved higher test scores than students who worked on these two lessons in the reverse order. The visual/verbal order of presentation proved superior. Transfer from one learning situation to another appears to have been facilitated by the visual/verbal order of presentation.

Results of Study No. 2 were as follows:

(1) The superiority of the visual/verbal order of presentation was replicated with different lesson content. Students took less time to complete a self-paced verbal program when the visual program preceded it than when it followed it.

(2) During the visual presentation, a pictorial mode of responding (selection of pictorial multiple-choice options) proved superior to a verbal mode of responding (selection of verbal multiple-choice options).

(3) There was a significant interaction between IQ and mode of response, with below average students doing better when they made pictorial rather than verbal responses to the visual presentation.

The results of both studies suggest the following strategy considerations: (1) that concepts are more easily acquired on the basis of discrimination practice to visual, demonstration events than on the basis of verbal lesson materials and more easily when responses to the visual demonstrations are pictorial rather than verbal; (2) that transfer from one learning experience to another is more likely to occur when a visual/verbal order of presentation is used; and (3) that transfer across modes is more likely to occur from learning situation to testing situation when learning is based on visual experience.

Results of Study No. 1 suggest that responses are more readily brought under the control of visual presentation when students respond actively than when they merely watch passively.

These results provide the basis for practical recommendations concerning the preparation and utilization of integrated film or TV lessons or of single concept films integrated with other media of instruction. For teaching concepts and principles:

- pictorial materials should be programmed to be capable, on their own, of teaching concepts.
- during such presentations, discrimination practice should be based on pictorial response options.
- programmed pictorial materials should be accompanied by but precede verbal materials.

It is suggested when this practice is followed, response difficulty can be lessened and transfer from one learning situation to another facilitated.

GENERAL INTRODUCTION

GENERAL INTRODUCTION

One of the principal functions visuals can serve in instruction, particularly in science instruction, is to provide a series of concrete examples that aid students to gain an understanding of the concepts and principles it illustrates (Gropper, 1963b). Student understanding may develop from an inductive experience with a variety of such related examples. Another possibility is that, following exposure to an abstract statement of a principle, visual examples may serve to facilitate its transfer or application to a range of appropriate contexts. A primary preoccupation of audio-visual research must therefore be the identification of parameters of visual presentations that make their use in either of these two roles optimal.

From a behavioral point of view, visuals may be said to do the job they were designed to do when student responses effectively come under their control. In everyday language, this simply means that students respond appropriately to them. Appropriate responding may consist of observation, identification, or description of relevant elements of visual events. It may consist of appropriate inference about or interpretation of such events. Stated in behavioral language, the goal of audio-visual research is to discover how responses to visual events, of whatever variety, are effectively brought under their control. Converging trends in research on film, television, and teaching machines suggest that such behavioral control is effectively brought about through active student responding during lesson presentation (Allen, 1957; Carpenter & Greenhill, 1963; Gropper & Lumsdaine, 1961; Postman, 1961; Schramm, 1962).

While there appears to be a broad consensus about the value of response practice during learning (Lumsdaine, 1961), there is far less consistency in the use of the term "active response." The term "active response" which has been used to describe student responses made during filmed, televised, or teaching machine instruction, has come to signify quite a variety of behavioral phenomena. For some, "active response" has meant simply that responses are to be made overtly. For others, it has meant that students should make unprompted, anticipatory responses, as in composing answers to fill-in questions. For still others, it has meant partially prompted, multiple-choice responses. And for still others, fully prompted "reading" responses or fully prompted "copy" responses appear to fall within the definition.

If response practice is to be made a critical part of audio-visual instruction so that responses may be brought under the control of visuals by means of it, it would do well to be clear from the outset, as to precisely what is meant by "active" responding. A brief review and redefinition of various terms used to describe responses appear to be in order.

DEFINITION OF ACTIVE STUDENT RESPONSE

The terms most often used in giving operational meaning to "active response" have had to do with distinctions between: "active" and "passive" responses, overt and covert responses, and implicit and explicit responses (Lumsdaine, 1963). Previous usage has at times tended to cloud the distinctions among these pairs. "Covert" and "implicit" have at times been used interchangeably. "Active" and "overt" as well as "explicit" and "overt" have also been used interchangeably. If there are practical implications to be drawn from the distinctions among these terms, it would be well to provide non-overlapping definitions for them. Not least among the possible outcomes would be the kinds of research questions which are posed and subsequently investigated.

Overt Vs. Covert Responses: Locus and Observability of Responses

Responses that are external to the subject making them and that are observable to an outside observer may be called overt. Examples of overt responses might include: such non-verbal motor behavior as manipulating a switch, swinging a golf club, or drawing a picture; or such verbal, motor behavior as writing an answer on paper, saying an answer aloud, reading aloud, or pointing to an answer On the other hand, responses internal to the subject without some form of instrumentation to make them observable, are non-observable to an outside observer. We may call these responses covert. Examples of covert responses might include, in addition to such non-verbal responses as kinaesthetic or perceptual responses, the verbal responses of: thinking, saying an answer to oneself, reading silently, or watching a live or filmed demonstration.

The observability of the behavior the instructor or the researcher is thus likely to be concerned with is largely a function of the locus of the response.

It is part of the scientific enterprise that independent observers be capable of agreeing on phenomena they are investigating. At least for the purposes of research on instruction, it is clearly desirable that responses to instructional sequences be observable and, as a result, measurable. One argument in favor of overt responding, therefore, is its value in promoting objective observation.

A recent annotated review of research on programmed instruction (Schramm, 1962) provides evidence that there are numerous studies on response mode which are not concerned with the overtness of response primarily for the objectivity of measurement it makes possible but are concerned with the value for learning of overt rather than covert responding. Most of these studies, however, fail to confine research on response mode merely to the distinction made here as to locus and hence the observability of the response. Adhering to the distinction made here, overt response is properly compared with covert response when reading aloud is compared with reading silently; or when blanks filled in aloud (or in writing) are compared with blanks filled in by saying words silently to oneself. Much of the research which seeks to compare overt and covert responding, is often a comparison of covert, silent reading with overt filling in of blanks. In this instance, fully-prompted reading responses are compared with partially-prompted or unprompted constructed responses. Thus phenomena which differ from one another with respect to more than the dimension of observability are often being studied in response mode comparisons.

Whatever benefit for learning the overtness or covertness of a response might eventually be demonstrated to have, and as defined here, there appears to be little reason to expect differences between the two, there is certainly value in requiring responses to be overt for research purposes. The scientific enterprise of investigating learning phenomena is thereby put on a more certain and verifiable basis. Also, in the practical instructional situation, requiring responses to be overt is one way to make certain that the student adheres to the task assigned him.

Active Vs. "Passive" Responses: The Degree of Response Prompting

Much of the controversy over response mode arises from differences of opinion, not about the overtness or covertness of responses but about the degree to which responses should be prompted. At one end of the prompting dimension is the fully-prompted response, where the subject is shown the response and then makes the same response himself. The reading response or the "copy" response (in linear programs) are examples of fully-prompted responses. The reader may read materials giving a full statement of what Archimedes' Law asserts. The copier may be asked to fill in blanks in the same statement, but the passage is available to him to copy. It is such responses, e.g., reading or copying, which are sometimes described as being "passive" or non-active.

At the other end of the response-prompting dimension are responses which are unprompted. Rather than copy a response, the student is expected to anticipate what it will be. He is expected to construct a response appropriate to the context presented to him. At this end of the prompting dimension, the context presented to the student represents a criterion situation, essentially similar to the post-instructional situation the student is being prepared to meet. He may be given such criterion questions as: What does Archimedes' Law state or what is a perfectly elastic body? The criterion context provides no prompts or assists to the student to help him to make the appropriate response. Such unprompted responding has been described as being "active."

Somewhere between the two extremes, the fully-prompted response at one end and the unprompted, anticipatory response at the other end, are the partially-prompted responses. Here, the student is given varying degrees of assistance in making responses. When he is expected to fill in a blank by constructing a response, he is given cues to aid him. Such cues are typically weakened in gradual fashion to prepare the student ultimately to make the unprompted criterion responses. Until that point, however, partial prompts are provided. They may be provided directly and immediately or they may be provided by means of just completed occasion for response practice (the just prior frame). In this latter instance, it is a case of a just completed behavioral sequence serving as a cue for a response yet to be made.

The multiple-choice response is another form of a partially-prompted response. Unlike the fill-in response where the student is expected to construct or produce a response on the basis of available prompts, the student is rather expected merely to recognize the correct response. He is expected to distinguish it from a series of options. The available options serve as a partial prompt for his response.

While "active" responding has been variously defined, sometimes described one way, at other times in other ways, it would appear that the key dimension has to do with the response task confronting the student and with the amount of help given the student in performing it (degree of prompting). It is not simply a case of producing vs. recognizing. Rather it appears to be a case of how much help is given in doing either. Thus, constructed and multiple-choice responses may both be said to be "active" with the degree of "activeness" being a function of the degree of prompting offered the responder. When response options are made sufficiently large in number, the multiple-choice response approximates the constructed response in the lack of prompting available. (Whether these two modes of response are equally effective in producing criterion behaviors, perhaps depends on the nature of the criterion behavior. It has been generally assumed that criterion construction responses can be produced only through some form of construction practice. Evidence from NAB programming efforts by Evans at TMI and by Gropper with his work with REP programs, suggests that concept learning through multiple-choice responding can lead to criterion constructed responses. For our purposes here, this, of course, is a side issue.)

Explicit Vs. Implicit: The Specifiability of S-R Relations

The term explicit has at times been made synonymous with overt, as in written responses, and implicit synonymous with covert, as in reading responses. It is perhaps more useful to refer to the explicitness of the relationship between stimuli and responses than to the explicitness of responses per se. When the occurrence of specified responses is under the control of or occasioned by specified stimuli, the relationship can be said to be explicit. It is the specifiability of the responses and the stimuli which prompt them which makes the relationship explicit.

To illustrate the explicit relationship between stimulus and response, we might use the following sample program frame:

> Explicitness of responding refers to the specifiability of the relationship between stimulus and response. The relationship between stimulus and response can be called explicit if it can be ______________________.

The relationship between the response "specified" and the stimulus material is explicit in the following sense. The stimulus material is identifiable or specifiable. It is a particular four lines of print with a blank in it or with a question calling for a response. That the stimulus is indeed operative and effective in prompting a particular response is ascertainable through empirical data. Frequency of response (e.g., error rates) provides the appropriate evidence.

Explicitness thus refers to the particularity and specifiability of both stimulus and response. While the stimulus material cited in the sample frame may be said explicitly to control a particular response, it should not be overlooked that other responses may, at the same time, also be made. Their occurrence is not solely under the control of the specified stimulus material. It is under the control of other, non-specified stimulus material, perhaps covert, mediating responses. Its occurrence is adventitious and not under the control of the instructor or the instructional materials he has created. When explicitness is attained, it is through the use of carefully prepared lesson content designed to prompt specified responses and/or through the use of instructions to the student designed to prompt responding per se.

Responding may be defined as implicit when either the effective stimulus or the response made is not specifiable or identifiable. When the relationship between stimuli and responses is implicit because either the operative stimulus or the response is adventitious, that is, not specified by the instructor, the instructor does not maintain control over the learning situation.

The so-called mediating responses, whether perceptual or symbolic, may be thought to be prime examples of implicit responses. (They are also covert.) While silent reading responses may be thought to be under the explicit control of words on the printed page, the accompanying symbolic responses, of whatever sort, are not under such control. Nor are the perceptual responses during a visual presentation apt to be completely under the explicit control of the presentation.

A central aim in programmed audio-visual instruction might very well be the increase in the amount of explicit control over responses at the expense of much that is typically implicit. This would seem to call, on the one hand, for an increased number of explicit occasions in which students would be expected to respond "actively" on cue. It would also seem to call for the systematic manipulation of stimulus factors such that specific perceptual or symbolic responses (albeit covert and non-active) are made more likely to occur. Research addressed to this latter objective could create occasions for testing the effectiveness of such stimulus factors by requiring responses mediated by perceptual or symbolic responses and specifically linked to them to be made overtly, on cue. In the course of everyday instruction, perceptual or symbolic responses might then be said to be under the explicit control of visual presentations despite the fact that it is other responses that are overt and that are "actively" made.

Paramount issues to be investigated in audio-visual research thus concern how responses whether overt written responses or covert perceptual or symbolic responses can be brought under the explicit control of stimulus features of audio-visual presentations.

RESPONDING TO VISUAL PRESENTATIONS

The evidence on the value that response practice has for learning does appear clouded due to the lack of clarity or consistency as to the distinctions made above about types of responses. Nevertheless, based both on theoretical considerations and on some empirical findings, some form of response practice does appear to have beneficial effects for learning. This has been the case in research on filmed, televised, and programmed instruction. It would therefore appear that some form of response practice might also be desirable during visual presentations. In terms of the distinctions made above, what form of response should be required during dynamic visual presentations? Should students watching a science demonstration designed to teach facts or concepts, whether it is presented live in the classroom or canned on film or on television tape, make overt responses? Should they make fully, partially, or unprompted responses? Must students watching a demonstration practice responses or is merely watching a well-prepared demonstration enough? Are there properties of a visual presentation which perhaps may preclude the necessity of response practice?

There is no conclusive evidence about instruction with verbal materials which would point to a clear advantage for overt responses over covert responses. Thus, it is possible to remain neutral, at least at this point in time, with respect to the desirability of overt responding during visual presentations. There is similarly inconclusive evidence as to the advantage of constructed responses (with varying degrees of prompting strength) over multiple-choice responding. It is therefore also possible to be neutral with respect to the desirability of various response modes during visual presentations.

While it is possible in the absence of empirical support to maintain a neutral view about the desirability of overt rather than covert responses or about fully-prompted rather than unprompted responses, it seems clear that no empirical support is needed for a view about the desirability of the explicitness of the relationship between visual stimulus elements in a demonstration and the responses made to them. A science of instruction requires a precise specification of S-R relations. In its absence the attribution of achievement results to particular features of a presentation appears unsupported and indeed capricious. Such results might be due to the presence of stimulus elements not identified or to responses made adventitiously rather than to responses predetermined necessary for subject matter mastery. As pointed out above, it is part of the scientific enterprise to depend on observable or measurable phenomena. It is similarly a part of the same enterprise to attend to explicit relations among phenomena. Research may ultimately show that it is necessary or unnecessary to require unprompted rather than prompted response to visual presentations. No such research is needed to take the position that it is necessary to make explicit the relationship between stimulus elements of a visual presentation and the responses to them (whichever mode of response may ultimately be demonstrated to be more effective).

A primary purpose in making the S-R relations explicit is to facilitate bringing the responses under the control of the stimuli in a systematic way. This is the aim, as pointed out above, of all instruction. The experiments reported in the next two sections, describe methods of exercising such control during visual presentations and the instructional advantages which may accrue from such control.

STUDY No. 1: AN INVESTIGATION OF RESPONSE CONTROL DURING VISUAL PRESENTATIONS

PROBLEM

Research on programmed instruction has made considerable contributions to our understanding of how learning comes about as responses are brought under the control of verbal stimuli. Considerably less is known about how responses can be brought under the control of non-verbal, visual stimuli and how such control can facilitate learning.

The problem of achieving stimulus control appears to be not too dissimilar for verbal and visual presentations. When verbal material is presented, it is important to determine in explicit fashion which responses are being practiced in the presence of the presented verbal stimulus materials. While complete control over all responses made while a student reads a printed frame is not possible, efforts are made to limit the probabilities of responses occurring other than the desired ones. In programmed instruction, printed frames of limited or circumscribed content are designed, with appropriate levels of cuing, such that specified responses are made more likely to occur in the presence of specified cues and contexts. The relationship between stimulus materials presented and responses practiced is made increasingly more explicit as the probability of particular responses being made increases. Responses to programmed verbal materials as a result are explicitly related to the verbal stimuli. They are also generally active in character. That is, in terms of the distinctions made earlier, they are guided by cues which gradually decrease in strength. They are active responses because they either are relatively unprompted or, in the criterion situation, are completely unprompted. Also, they are generally overt, providing empirical evidence not only as to the explicitness of the relationship between stimulus and response but also as to the correctness of the response.

It appears equally desirable to insure that responses to visual, non-verbal presentations also are explicit, active, and overt (the latter particularly in research studies). It appears reasonable to expect that responses are more apt to be brought under the control of non-verbal, visual stimuli when these conditions are met. The research reported here represents one of the first attempts to "program" visual presentations in such a way as to achieve such control.

The goal of achieving stimulus control during visual presentations, however important this might be, is nevertheless only a formal or procedural requirement. It refers primarily to the range of necessary conditions under which instruction may be optimally offered. It lacks however a specific or substantive description of the functional role that stimulus materials, in this instance non-verbal, visual stimuli, can play in instructional strategies designed to promote specific learning tasks. It does not specify, for example, how visual examples might fit into an instructional strategy designed to teach concepts and principles. Thus, this study, in its aim of "programming" visual presentations is also concerned with an exploration of how instructional strategies can profitably incorporate non-verbal, visual stimulus materials as a means of promoting specified learning tasks. In this instance, it is concerned with ways in which science demonstrations can be used to facilitate student learning of science concepts and principles. It thus addresses itself to the problem of developing a strategy whereby non-verbal, visual materials can be used to facilitate a verbal, conceptual learning task.

This study is in summary concerned with the following specific problems:

1. In the interest of developing an instructional strategy for using non-verbal, visual materials:
    (a) can science concepts and principles be acquired from a series of solely visual examples? what are the programming techniques which might bring this about?
    (b) how can programmed visual and verbal presentations be optimally integrated? should concrete visuals precede the more abstract verbal material or does the reverse order more readily facilitate student learning of concepts and principles?
2. In the interest of bringing student responses under the control of a visual presentation:
    (a) when programmed visual presentations are offered, is there any advantage of active responding over "passive" viewing?

METHOD

Experimental Materials

Four experimental lessons were developed each of which was designed to fulfill the same objective, namely, to develop student understanding of Archimedes' Law. Two of the four versions were entirely visual; the remaining two entirely verbal. The two visual versions were nearly identical in all respects except one. They differed from one another in that, through the use of appropriately designed occasions, students were encouraged to respond actively to one and not to the other; that is, in one version students were instructed to make responses, generally of a multiple-choice variety, to stimulus situations; in the second version, students were merely expected to watch a presentation which neither afforded an opportunity for nor encouraged active responding. The two verbal versions differed from one another in the same way; here, however, the active responses made were of the constructed variety.

1. Visual lesson. - Both visual lessons were programmed. They consisted of repetitive demonstrations carefully sequenced to enable students to make appropriate responses to them. Only in the "active response" version, however, were students required actively to make responses. They were required to make discriminations about the occurrences they saw. Explicit occasions were provided for them to practice discriminations and, on the basis of such practice, it was intended that students acquire the concepts and principles they needed to be able to predict future occurrences. In the alternative version, no requirement was placed on the students other than merely to watch the presentation.

Both versions of the visual lesson were entirely visual. No oral nor printed verbal material was used to describe or to explain the events presented. The burden of instruction was solely on the visual events presented.

It should be pointed out, however, that despite the fact that the content of Archimedes' Law was taught through demonstrations only, words were used at strategic places. Their primary function was to encourage and direct student responding. They were in no sense designed as cues for particular responses. The instructor, following a sequence of actions, might say: "If I do it to this one, what will it be like here; will it be like this, like this, or like this?" During the spoken phrases "like this, etc." a stagehand might point to three different readings on the same scale. Thus, although it is evident that asking a question tended to direct or limit the kinds of response that might be made, it did not cue the actual, correct response. Cuing of correct responses was accomplished solely by the sequence of visual events.

Briefly summarized, the demonstrations that were shown illustrated the relationships between the apparent loss of weight for a submerged object, the weight of the water it displaced, and the magnitude of the buoyant force exerted on it. Some of the discriminations that were required in order to make students gain an understanding of these relationships may be more effectively described by means of photographs taken during the recording of the demonstrations.

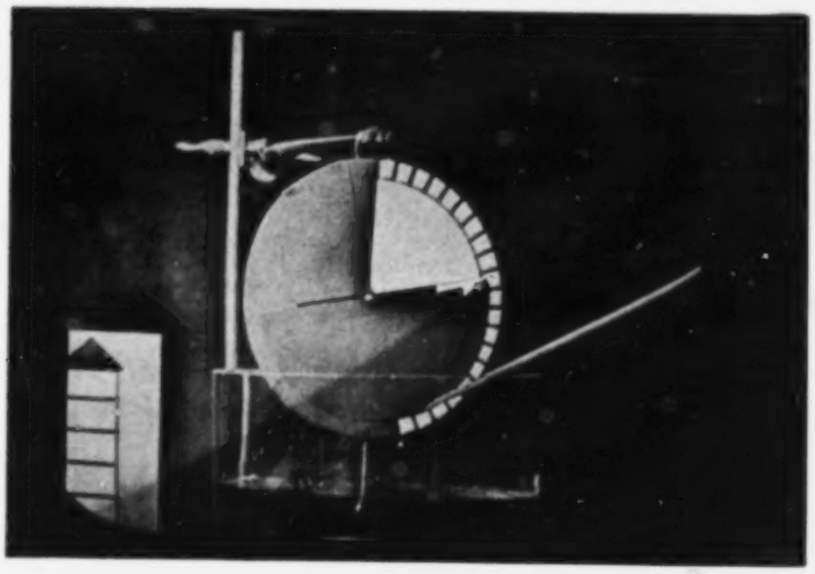


Figure 1

The apparent loss of weight for submberged objects was demonstrated by submerging an object attached to a hanging scale. When the object was submerged, the counterclockwise excursion of the scale pointer indicated the apparent loss of weight (see Fig. 1).

After the demonstration was repeated with one or two different sized objects (see Fig. 2), students were required to predict what the scale readings would be when a new object was submerged in water.

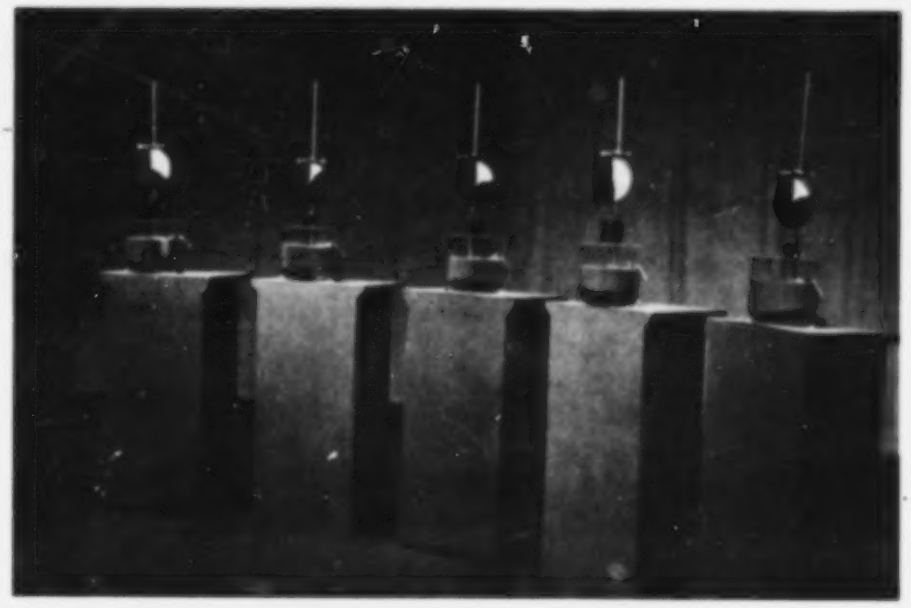


Figure 2

They were presented with a multiple choice situation enabling them to predict what would happen to the scale reading if the new object were submerged. Figures 3 and 4 show scenes indicating the pictorial choices that were presented to them.

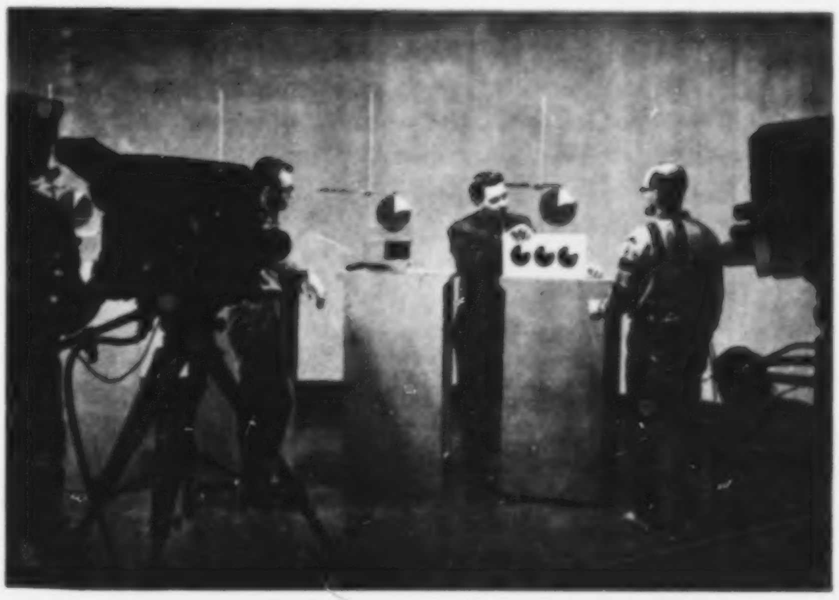


Figure 3

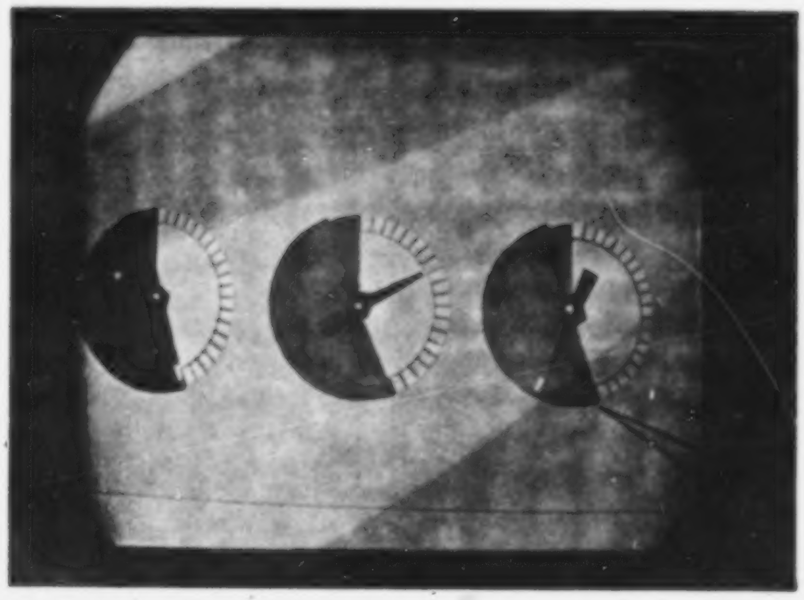


Figure 4

From left to right, the possible choices were: no change, a decrease in scale readings, and finally an increase in scale readings. Following an occasion for student responding, the new object was submerged and the actual decrease in the scale reading shown. The actual occurrence provided students with feedback as to the correctness of their own responses. Students were thus aided to learn the principle of the "apparent" loss of weight of submerged objects by practicing discriminations about differences in scale readings for objects weighed in air and in water.

Another set of discriminations practiced had to do with the size of an object and the resulting displacement of water (measured by the amount and weight of the overflow). Following repetitions of a demonstration illustrating this interrelationship and the opportunity for students directly to compare object sizes and amounts of overflow (see Fig. 5), the student was expected to predict the amount of overflow that would occur for an object differing in size from those already used in the demonstration. Figure 6 shows the choices offered students and also shows the identification of the correct response providing them with confirmation as to the amount of overflow to be expected for the trial object. Discrimination practice here built up the principle concerning the relationship between object size and the amount of the overflow it caused.

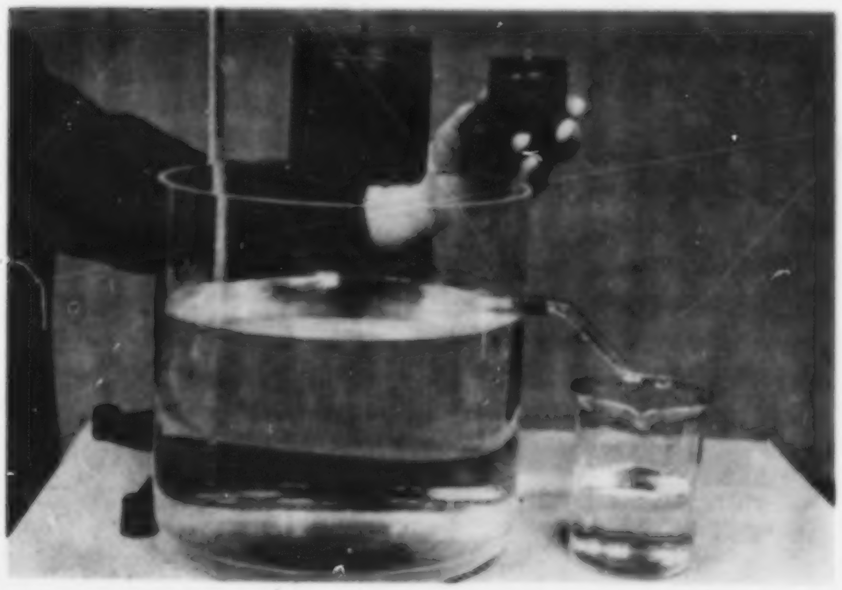


Figure 5

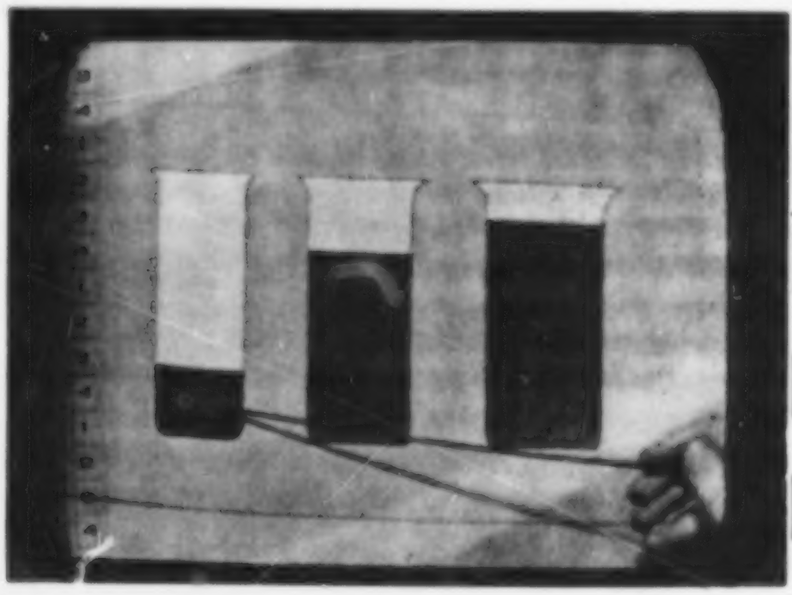


Figure 6

Still another discrimination acquired was that involving the weight of the overflow and the magnitude of the buoyant force. Buoyant force had been illustrated analogously in prior sequences by a flashing arrow. As shown in Figure 7a, the force was represented by a vector with its magnitude proportional to the size of the vector. As Figure 7b shows, the instructor presented two amounts of overflow.

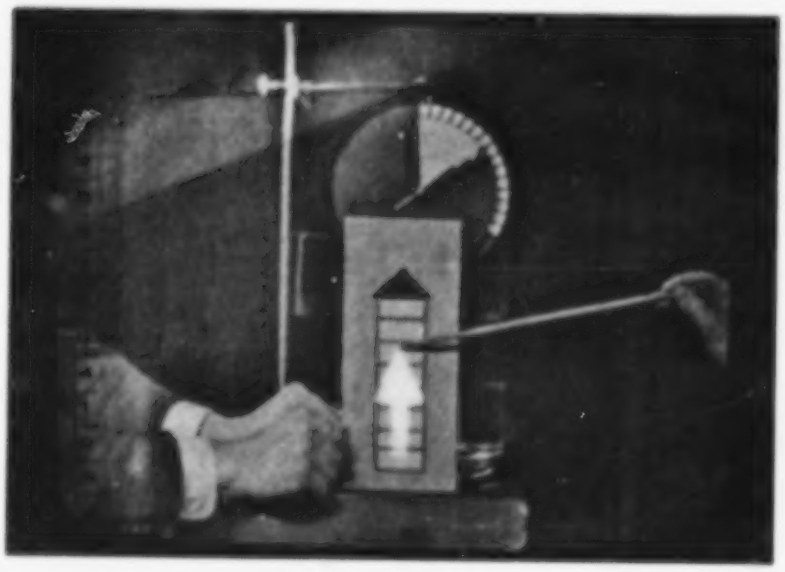


Figure 7a

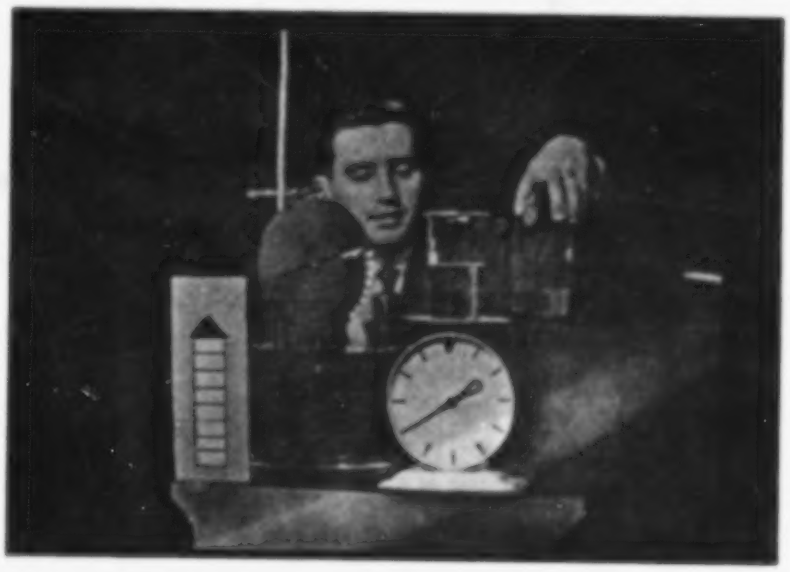


Figure 7b

He then showed the relative difference in buoyant force that resulted, or in sub-criterion portions of the lesson he required students to predice the relative magnitude of the buoyant force which would result if the amount of overflow was like that found in a second or new beaker.

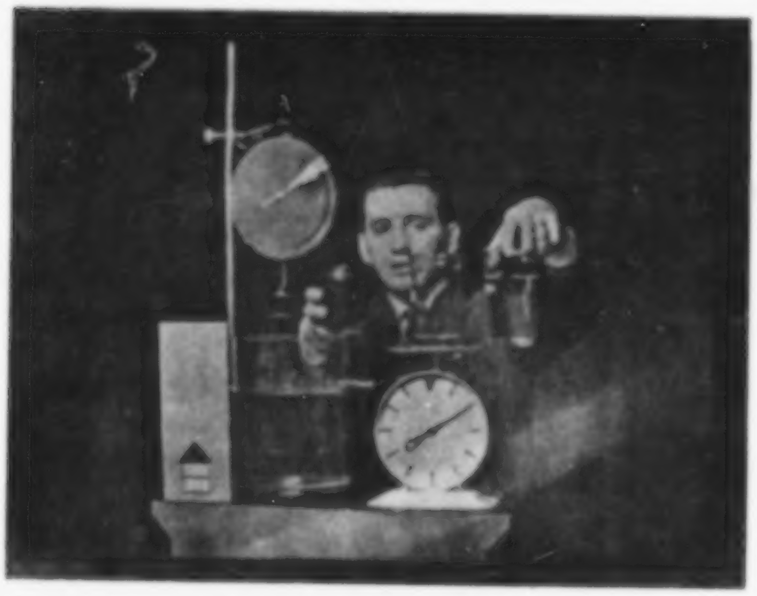


Figure 8

The relationship between object size, amount of overflow, and buoyant force was similarly illustrated, as shown in Figure 8, providing students with an occasion to predict the relative size of the buoyant force that would result when different sized objects were submerged.

Similar discriminations were practiced throughout the entire lesson until all the relevant relationships involved in Archimedes' Law, as described in the lesson objectives, were covered. In later instructional sequences, students were expected not only to select the correct answer from among pictorial choices, they were also expected to construct responses. For example, having been shown the weight of the overflow, they were required to indicate the magnitude of the buoyant force for a particular submerged object.

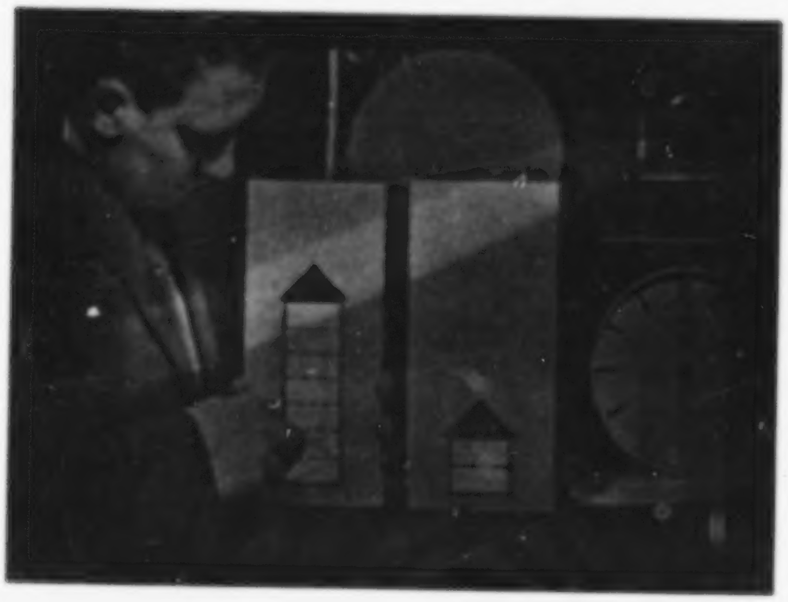


Figure 9

As shown in Figure 9, the instructor illustrates how they were to indicate their answer. If they thought the buoyant force was of a two-unit magnitude, they were instructed to cross-out two units on their response forms. (The pointer on the dietary scale indicates that the overflow in this example weighted six units. The correct response, thus, would consist of crossing out six units on the vector.)

Students had response forms which, in the case of multiple-choice responding, paralleled the choices presented on the screen. Constructed responses were made by marking X's against or circling appropriate scale values. Appendix B for Study No. 1 in this volume contains the workbook for the visual lesson.

The visual lesson was prepared so as to enable students to respond appropriately in a visual criterion situation, namely, being able to make discriminations about the identity in values for the weight of the overflow, the magnitude of the buoyant force, and the magnitude of the apparent loss of weight. The lesson was programmed and recorded on tape.

It was then shown to six trial subjects similar in age and background as those who would participate in the experiment proper. Based on the results of this tryout procedure, a second and a third version were prepared and recorded. The third and final version produced a relatively low average error rate of 10% and was retained for the experiment. This version was approximately 45 minutes in duration.

The alternate version of the visual lesson consisted of the same sequences, as just described. However, they did not provide occasions for student responding nor did they offer alternative possible outcomes. Students watching this version merely saw the correct relationships among events visually demonstrated. They were not explicitly instructed to predict outcomes for the new events they were to see demonstrated, although as in any form of conventional instruction, students may on their own have made anticipatory responses, anticipating the events yet to be present. To make up for the extra time that was required by and that might possibly favor the group responding to the original version, some sequences were repeated. This alternate version was approximately 35 minutes in duration.

2. Verbal lesson. - A verbal lesson was prepared based on the same lesson objectives that guided the preparation of the visual lesson. That is to say, the facts and concepts having to do with Archimedes' Law were spelled out in behavioral terms and guided the preparation of both versions of the lesson. The verbal lesson was programmed and tried out several times. During these tryouts students were allowed to pace themselves and careful records were kept of the amount of time students required to complete particular response segments. Since the TV presentation would be paced and a fixed time allotted to each response segment, these records were later used as a basis for determining the appropriate duration of presenting each of these response segments.

Following a tryout and revision resulting in a programmed verbal lesson that yielded an average error rate of approximately 10%, the lesson was recorded on video-tape (see Figs. 10 and 11).

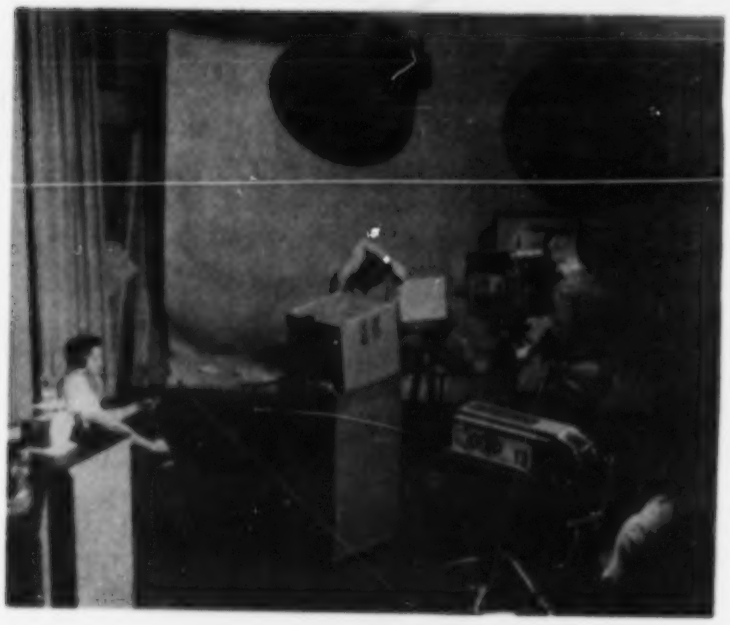


Figure 10

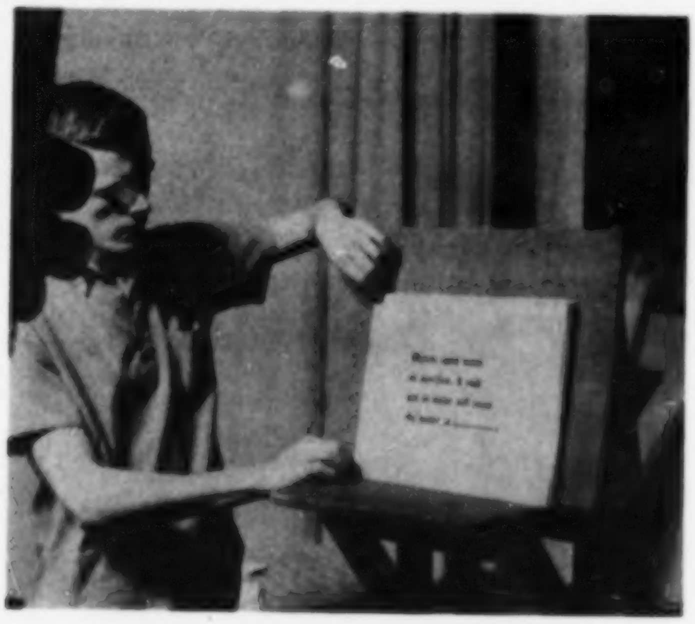
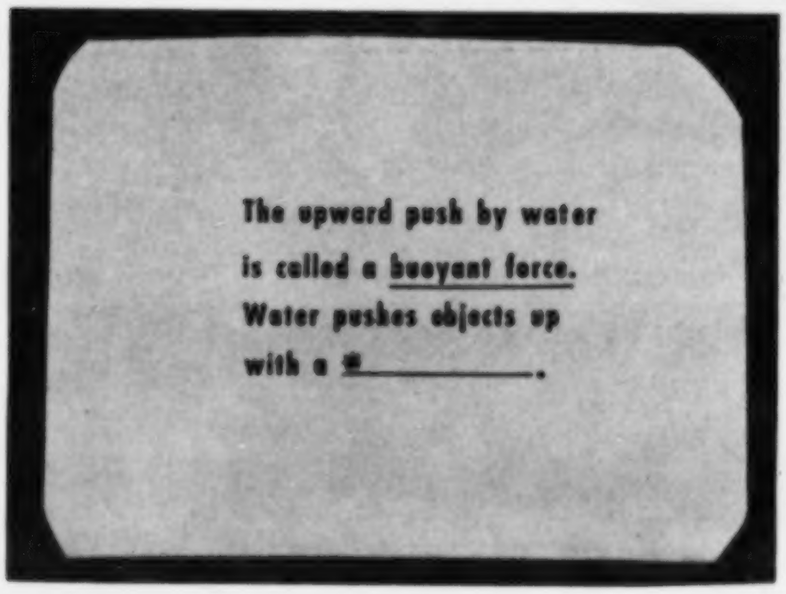


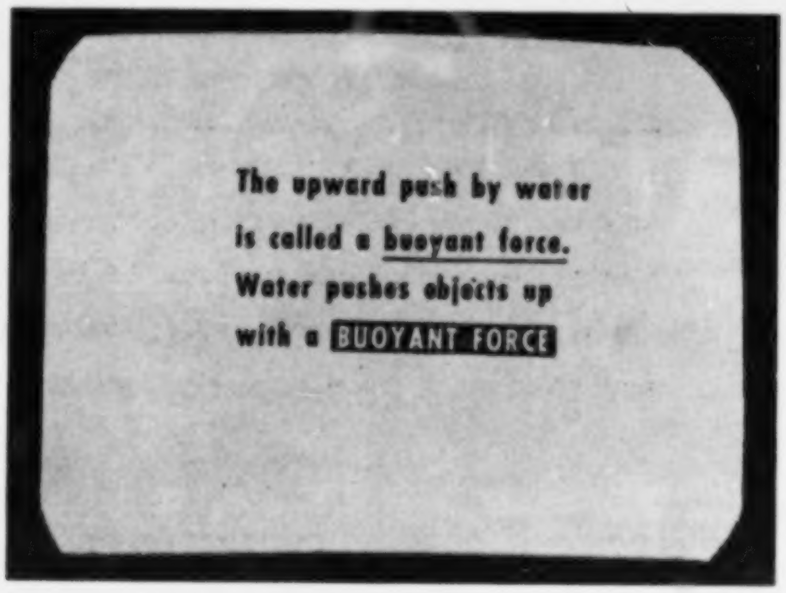
Figure 11

The lesson consisted of sentences containing blanks which students were required to fill in (on their work forms). Following the allotted duration for each sentence, the correct response in bold print and in another color was popped on in the blank slot (see Figs. 12 and 13). After sufficient time for students to read the correct response, the card was pulled revealing the next card containing a sentence with a blank space to be filled in. Although this was essentially a visual presentation of printed material, the instructor did systematically call out the numbers of the pages students were supposed to be working on and also called their attention to the screen when the response was being presented on the screen. This served two functions. It tended to preclude an entirely soundless and potentially monotonous presentation. It also served to prepare students for changes in the presentation and thus could aid all students in keeping pace with the presentation.



The upward push by water
is called a buoyant force.
Water pushes objects up
with a *________.

Figure 12



The upward push by water
is called a buoyant force.
Water pushes objects up
with a BUOYANT FORCE

Figure 13

The verbal lesson was almost entirely verbal in nature. Occasionally there were brief camera shots of an object on a scale or an object submerged under water. These shots were very brief and did not include any action. They served merely to facilitate the verbal programming by precluding the need for additional, and possibly needless, time-consuming sentences. The entire verbal lesson lasted approximately one hour.

The alternate version of the verbal lesson provided students no occasion for responding. They were shown only sentences with blanks already filled in (as in Fig. 13). Each sentence was allotted approximately as much time as was allotted for students to respond in the original version. The time allotted for introducing the correct answers was eliminated. In general, time for each sentence was reduced, primarily because the durations allotted for responding would have been excessive from the point of view of maintaining student attention and interest (as pretesting had indicated). This version of the lesson lasted approximately 40 minutes. Appendix A for Study No. 1 in this volume contains the entire verbal program.

Design and Experimental Variables

The four experimental lessons were combined and compared in various ways to answer a number of research questions. There were eight experimental groups as summarized in Table 1. Except for groups seven and eight, all groups were given two versions of the lesson on Archimedes' Law, but in different orders and combinations.

TABLE 1. DESIGN OF EXPERIMENT

	Active Response			
	Group 1	Group 2	Group 3	Group 4
presentation 1	Verbal Lesson	Verbal Lesson	Visual Lesson	Visual Lesson
presentation 2	Verbal Lesson	Visual Lesson	Visual Lesson	Verbal Lesson

	No Active Response		Active Response	
	Group 5	Group 6	Group 7	Group 8
presentation 1	Visual Lesson	Verbal Lesson	Visual Lesson	Verbal Lesson
presentation 2	Verbal Lesson	Visual Lesson		

This design makes it possible to investigate the following research problems: (a) the feasibility of programming visual demonstrations; (b) the relative effectiveness of verbal and visual programs; (c) the optimal order of presenting both verbal and visual programs; and (d) the effect on learning of active vs. non-active responding to verbal and visual programs. A comparison of results of achievement tests administered to the several experimental groups before, immediately after, and on a delayed basis permits an exploration of the effects on learning of the following variables:

- - active responding vs. no active responding
- - visual vs. verbal modes of presentation
- - order of presentation.

Alternate forms of an achievement test were developed to cover all the material specified in the statement of lesson objectives. The tests were pre-tested and items revised based on an administration to a class which would not participate in the experiment but which was similar in grade level to the classes that would participate. The basic difference between them was that the "pre-test" group had already received classroom instruction in Archimedes' Law. Item difficulty level and item discrimination power was based on an analysis of their test results. Items were revised based on these results.

The achievement test was divided into two parts: a verbal part and a visual part. The verbal part of the test consisted of multiple-choice questions about concepts relating to Archimedes' Law, including some numerical computation. The visual part of the test consisted of pictorial representations of objects, scales, beakers containing displaced liquid, etc. Problems, although verbally stated, depended for their solution on students visually perceiving objective facts and relationships. The problems approximated those with which students had to deal during the visual program and with which they might have to deal in the physical world. Appendix C for Study No. 1 contains all achievement tests used.

Subjects

Subjects were eighth grade students drawn from classes which regularly watched junior high school science televised over station WQED in Pittsburgh. Although it was not feasible to assign students from each class randomly across all eight experimental conditions, it was possible to make random assignments to sets of two experimental conditions, resulting in a quasi-experimental design. Students from each class were assigned at random to one condition in each set of experimental conditions and the other member to the second condition. The sets to which such random assignments were made consisted of: (a) groups 1 & 2; (b) groups 3 & 4; (c) groups 5 & 6; and (d) groups 7 & 8 as shown in Table 1.

Twenty-five students were assigned to each of the eight experimental groups.

Procedure

Two weeks prior to the date in which he would participate in an experiment, each student took an achievement test to determine the level of his prior knowledge of the subject matter. Students were then brought into the studio of WQED on the day of the experiment (conducted on two separate Saturdays) to view the experimental lessons over closed circuit television. One group of subjects viewed one version of the lesson on monitors in one studio, while a second group viewed another version (according to which experimental group they belonged) in another studio (see Figs. 14 and 15). Students then took one form of the achievement test. Following a ten-minute break, students entered the alternate studio to receive their second lesson (either a repetition of the first or another version as per the design of the experiment). The alternate form of the test was administered following the second version of the lesson. Two weeks later the first form of the test was administered once again, this time in the schools. Approximately four months later students were again tested for retention.

Figure 14

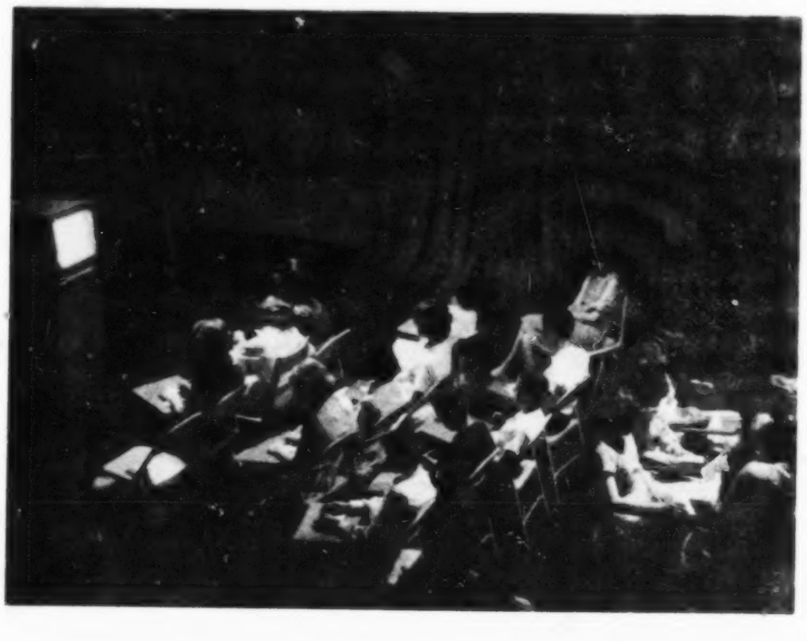


Figure 15

RESULTS

The results of the present study have been organized around analyses of achievement data obtained from the following experimental comparisons: (1) a comparison of groups receiving instruction on Archimedes' Law either from a solely visual lesson or from a solely verbal lesson; (2) a comparison of groups receiving instruction from various combinations or orders of visual and verbal presentations; and (3) a comparison of groups receiving instruction from either an active response presentation or from a "passive" or non-active response presentation.

1. Comparison of Visual and Verbal Programs

The results of an achievement test administered to students immediately after seeing either the visual program or the verbal program were analyzed to determine whether students made a significant gain in their knowledge of Archimedes' Law. A separate gains analysis (posttest minus pretest scores) was performed for students who had seen only the visual program. A similar analysis was performed for students who had seen only the verbal program. The results of these analyses are summarized in Table 1.

Table 1

Comparison of Gains in TOTAL Test Scores
for Students Receiving Either a Visual or a Verbal Program
(total test score possible = 38 points)

Groups	Pre-Test	Post-Test	Mean Gain	S. D.	t	df	p
Visual Program	20.1	25.9	5.8	(4.4)	8.4	39	.001***
Verbal Program	20.7	25.8	5.1	(5.0)	6.4	39	.001***
Difference in gains between groups			.7		F=.41	1/76	-

***significance at the .1% level

a. Visual program. - On a test, in which a total of 38 points was possible, students who watched and responded to the "active response" version of the "visual" program made an average gain of 5.8 points.

These students had averaged approximately 20 points on the pretest or approximately 50% of the total possible. A t-test for difference scores showed this gain from pre- to posttest to be significant at the .001 level.

b. Verbal program. - Students who watched and responded to the "active response" verbal program made an average gain of 5.1 points on the total test score. A t-test for difference scores showed this gain from pre- to posttest also to be significant at the .001 level.

c. Visual vs. verbal programs. - There were significant gains on total test scores from pre- to posttest for both the visual group and the verbal group. However, as shown on the bottom of Table 1, there were no significant differences between the gains made by the visual group and by the verbal group. (Complete results of the analysis of variance are reproduced in Table 1 in Appendix D for Study No. 1.) After receiving instruction on Archimedes' Law, both groups made gains on the achievement test of approximately 25%. However, significant differences were found between visual and verbal groups when the visual and verbal portions of the achievement test were analyzed separately. The achievement test including both pictorial and verbal items is reproduced in its entirety in Appendix C for Study No. 1. Table 2 summarizes the performance on the visual test for students who had received either the verbal program or the visual program.

Table 2

Comparison of Gains in VISUAL Test Scores
for Students Receiving Either a Visual or a Verbal Program
(total score possible = 16 points)

Groups	Pre-Test	Post-Test	Mean Gain	S. D.	t	df	P
Visual Group	9.1	11.5	2.35	(2.98)	5.00	39	.001***
Verbal Group	9.6	10.5	.95	(2.81)	2.16	39	.04*
Difference in gains between groups			1.40		F=4.55	1/76	.05*

***significance at the .1% level; *significance at the 5% level or better

The total possible score on the visual portion of the test was 16. As can be noted in the upper portion of Table 2, both groups made gains over their pretest level which were statistically significant. An analysis of variance showed the difference in gains on the visual test between the verbal program and visual program groups to be significant at the 5% level. The group of students who had watched the visual program outperformed the group of students who had watched the verbal program, as indicated on the bottom of Table 2. Students who had watched the verbal program made a gain of only 10% on the visual or pictorial test as against a gain of approximately 25% made by the students who had watched the visual program. (Complete results of the analysis of variance are reproduced in Table 2 in Appendix D for Study No. 1.)

On the verbal portion of the test, no overall significant difference was found between the visual and the verbal groups. An analysis of variance did, however, show a significant interaction between type of program watched and IQ. Table 3 presents the results of the analysis of variance indicating that the interaction between IQ and type of program watched was significant at the 5% level.

Table 3

Analysis of Variance Comparing VERBAL Test Scores for Students Receiving Either a Visual or a Verbal Program

	Sum of Squares	df	Mean Square	F
Type of Program	10.51	1	10.51	.96
IQ	2.11	1	2.11	.19
Type of Program x IQ	49.62	1	49.62	4.56*
Within	827.95	76	10.89	

*significance at the 5% level

Table 4 summarizes the gains on the verbal test made by high and low IQ student who watched either the visual or verbal programs. The number of points possible on the verbal test was 22. Subsequent t-tests performed separately for the high and low IQ groups indicated that only for the high IQ group was the difference between verbal and visual groups significant. Among high IQ students, those who watched the verbal programs made a significantly higher gain in achievement than did those who had watched the visual program. The reverse was true for low IQ students, but this finding was not statistically significant.

Table 4

Comparison of Gains in VERBAL Test Scores
for High and Low IQ Students
Receiving Either a Visual or a Verbal Program
(total score possible = 22 points)

Groups	Pre-Test	Post-Test	Mean Gain	S. D.	t	df	P
High IQ							
Visual Program	13.2	15.7	2.5	(2.5)			
Verbal Program	13.0	17.8	4.8	(3.4)			
Difference in gains between groups			2.3	(4.2)	2.42	19	.03*
Low IQ							
Visual Program	8.8	13.2	4.4	(3.1)			
Verbal Program	9.3	12.8	3.6	(3.7)			
Difference in gains between groups			.8	(4.5)	.85	19	.43

*significance at the 5% level or better

2. Comparison of a Visual/Verbal vs. a Verbal/Visual Order of Presentation

During the course of the entire experiment some students ultimately received both a visual program *and* a verbal program. One group received the visual program first followed by the verbal program. A second group received the programs in the reverse order. Of primary interest was a comparison of these two orders of presentation. Before this comparison was made, however, a four-way analysis was performed with two groups serving as control groups. One group received the visual program twice;

a second group received the verbal program twice. The results of this analysis are summarized in Table 5.

Table 5

Comparison of Gains in VERBAL Test Scores
for Students Receiving Different Orders of Presentation
(total score possible = 22 points)

	Immediate Posttest		Delayed Posttest[+]	
Order of Presentation	Mean Gain	S. D.	Mean Gain	S. D.
visual/verbal	6.28	(3.37)	5.36	(3.72)
verbal/verbal	4.86	(3.14)	4.07	(3.94)
verbal/visual	3.50	(4.45)	3.21	(4.84)
visual/visual	2.50	(2.90)	2.64	(3.18)
Analysis of difference in gains between groups	F=2.91* df=3/48		F=1.14 df=3/48	

[+] **administered 2 weeks after presentation; *significance at the 5% level**

On the test administered immediately after students received two programs (in whatever combination or order), no significant differences were observed between groups on total test scores. Significant differences were observed when the verbal items alone were considered. (The analysis of variance is summarized in Table 3 in Appendix D for Study No. 1.) As shown in Table 5, the group receiving the visual/verbal order of presentation made the highest gains, followed by the verbal/verbal, verbal/visual, and visual/visual groups. While the same rankings were obtained on a delayed test administered two weeks after the experimental session, the differences no longer were significant. (The analysis of variance for this latter comparison appears in Table 4 in Appendix D for Study No. 1.)

More detailed analyses revealed that the visual/verbal order of presentation was generally superior to the verbal/visual order of presentation. Table 6 contrasts the gains made by groups receiving these different orders of presentation on an immediate posttest, on a test two weeks later, and on a test four months later.

Table 6

Comparison of Gains in TOTAL Test Scores
for Students Receiving Different Orders of Presentation
(total test score possible = 38 points)

	Immediate Posttest		Two Week Delayed Test		Four Month Delayed Test	
Order of Presentation	Mean Gain	S. D.	Mean Gain	S. D.	Mean Gain	S. D.
visual/verbal	7.57	(4.70)	5.52	(5.31)	5.21	(4.43)
verbal/visual	4.52	(4.82)	3.47	(5.49)	3.29	(4.59)
Analysis of difference in gains between groups	F=5.75* df=1/20		F=3.52 df=1/20		F=1.57 df=1/20	

*significance at the 5% level

The visual/verbal group made greater gains on total test scores on all three occasions, but the difference between groups was significant only on the immediate posttest. (The analysis of variance for these comparisons appear in Tables 5, 6, and 7 in Appendix D for Study No. 1; these results are based on an analysis of matched groups.)

When the pictorial test questions are excluded from the analysis and only the verbal portion of the test is examined, the superiority of the visual/verbal order of presentation remains. In this analysis, however, as summarized in Table 7, the difference between the two orders of presentation are statistically significant in two of the three analyses.

Table 7

Comparison of Gains in VERBAL Test Scores
for Students Receiving Different Orders of Presentation
(total score possible = 22 points)

	Immediate Posttest		Two Week Delayed Test		Four Month Delayed Test	
Order of Presentation	Mean Gain	S. D.	Mean Gain	S. D.	Mean Gain	S. D.
visual/verbal	5.48	(3.23)	4.71	(3.42)	5.36	(2.50)
verbal/visual	3.05	(4.19)	3.09	(4.17)	2.50	(3.92)
Analysis of difference in gains between groups	F=5.19* df=1/20		F=1.97 df=1/20		F=5.69* df=1/24	

*significance at the 5% level

On all three test occasions, immediate, two-week delay, and four-month delay, the visual/verbal group outperformed the verbal/visual group. (The results of the analysis of variance for these comparisons appear in Tables 8, 9, and 10 in Appendix D for Study No. 1.)

3. Comparison of Active Response and Non-Active Response Groups

Because the visual/verbal order of presentation was generally superior to the verbal/visual order, it was subjected to further analysis. Two additional groups were compared. Both groups had received the visual/verbal order of presentation, but while one responded actively to the visual and verbal lessons, the second group merely watched them.

Although total test scores for the active response group were uniformly higher than for the non-active response group, the difference between them was not significant. However, analysis of the verbal portion of the test, excluding both the pictorial test items and computational items, revealed significant differences favoring the active response group. The analysis of variance of results for the comparison of the active and non-active response groups appears in Tables 11-14 in Appendix D for Study No. 1. As can be seen in Table 8 below, the active response group scored significantly higher on three out of four comparisons.

Table 8

Comparison of Gains in VERBAL Test Scores
for Active Response and Non-Active Response Groups
(total score possible = 17 points)

	Test After Visual Presentation		Immediate Posttest		Two Week Delayed Test		Four Month Delayed Test	
Groups	Mean Gain	S. D.	Mean Gain	S. D.	Mean Gain	S. D.	Mean Gain	S. D.
active response	3.56	(2.81)	4.78	(3.00)	4.33	(3.07)	4.00	(2.45)
non-active response	1.22	(3.30)	3.17	(2.36)	1.61	(2.57)	.58	(2.18)
Analysis of difference in gains between groups	F=4.71* df=1/30		F=3.11 df=1/30		F=7.61** df=1/30		F=11.32** df=1/20	

**significance at the 1% level; *significance at the 5% level

Following the presentation of the visual lesson only, during which one group responded actively while the other merely watched, a test was administered. The superiority of the active response group was statistically significant at the 5% level. On an immediate posttest, administered after both the visual and verbal lessons were presented, the active response group still outperformed the non-active response group, but the difference between them did not reach statistical significance. However, delayed tests administered two weeks and four months later resulted in differences favoring the active response group which were both statistically significant at the 1% level. The longer the delay, the wider the difference between the active response and the non-active response groups became.

DISCUSSION

The purpose of this study has been two-fold: (1) to explore the conditions under which student responses can effectively be brought under the control of non-verbal, visual stimuli; and (2) to explore possible instructional strategies in which non-verbal, visual stimulus materials might be used to facilitate a verbal, conceptual learning task. The data just presented will be treated in terms of their relevance to these two main issues.

BRINGING RESPONSES UNDER THE CONTROL OF VISUAL STIMULUS MATERIALS

If all we mean by "stimulus control" is that students make appropriate responses to specific stimuli, then evidence that stimulus control has been achieved must come from student responses themselves. The most direct evidence that responses were in fact systematically brought under the control of specific elements in either the visual presentation, the verbal presentation, or both comes from an inspection of responses made during the presentations, that is, responses made on cue to the stimulus materials themselves. Based on workbook protocols obtained during program tryouts and during the experimental sessions, it is apparent that the frequency of correct responses to the visual presentation was quite high (approximately 85%). This suggests that responses made during the "active response" presentation were in fact effectively brought under the control of the visual stimuli. However, a direct comparison of "correct-response" frequencies for this, the experimental group, and for the control group is not possible, since the control group (the non-active response group) was not required to respond overtly. Thus, the most direct evidence for comparing how well alternative treatments achieved stimulus control is not available.

Looking at the less direct, less immediate evidence of achievement test results, it is possible to compare the two treatment groups observed. The two treatment groups, it will be remembered, differed only on the basis of whether or not they responded actively, making anticipatory responses. Visual test items did not differentiate between the two treatments under discussion here (nor generally in any other comparisons in this study save one). On verbal test items, however, the group that responded actively clearly surpassed the group that merely watched the visual and verbal presentations. On a test administered after the visual presentation only, there was a statistically significant difference in gain scores; the active response group outperformed the "passive" watchers. Further, as noted in Table 8, on tests administered at various intervals after both the visual and verbal presentations were completed, the differences in gain scores observed between the two groups became progressively larger. While the gain scores for the active response groups declined moderately from the immediate test to the two-week delayed test to the four-month delayed test, the gain scores for the passive watchers declined sharply. The longer the delay in measuring retention, the more clearly was the active response group favored.

These results showing the beneficial effect of active responding both on acquisition and on retention are not particularly novel. They are consistent with majority findings from a large body of research on "participation techniques" (Allen, 1957). What is novel, however, is the extension of these findings to presentations that include programmed, solely visual lessons designed to teach verbal concepts. These lessons were programmed in such a fashion as to bring student responses systematically under the control of the non-verbal, visual stimulus materials. The evidence reported here indicates that for this purpose active responding is superior to passive viewing. In view of this finding, discussion of succeeding results and issues therefore involves "active response" groups only.

Save for a comparison of active vs. non-active responding, it was not the purpose of this study to compare experimentally variations in the programming techniques used to bring about stimulus control. A discussion of the specific programming techniques and procedures used to bring responses under stimulus control might therefore be best postponed until after Study No. 2 is reported, a study that used the same techniques as were used in the work being reported on here.

THE ROLE OF VISUALS IN INSTRUCTIONAL STRATEGIES

While achievement test results bear only indirectly on whether or not stimulus control is attained, they do bear directly on whether effective instructional strategies have been devised. On the strength of the results obtained here, that is, (1) that non-significant differences in total test scores between visual and verbal treatments were obtained and (2) that relatively high achievement levels were obtained for both treatments, it is apparent that programmed discrimination practice involving solely visual events can effectively teach verbal concepts and principles. In reaching this objective, no differences between visual and verbal presentations were observed on total test scores. However, differences in the relative effectiveness of the visual and verbal presentations were revealed by separate analyses based on scores on either the visual or the verbal test items.

Individual Differences and Mode of Presentation

Save for one comparison to be noted below, visual test items neither differentiated between treatment groups nor between ability levels. However, as measured by verbal test items and noted in Tables 3 and 4, there was a significant interaction between IQ and mode of presentation. While above average students appear to have profited more from the verbal presentation than from the visual presentation, below average students tended to profit more from the visual presentation. In subsequent t-tests only the former finding proved statistically significant.

Although the results favoring a visual presentation for below average students failed to reach statistical significance, they are consistent with findings of other studies and are therefore suggestive (Kanner, Runyon, & Desiderato, 1954; Gibson, 1947; Vernon, 1946). In Study No. 2, described in detail in the second part of this report, a statistically significant interaction was observed between IQ and mode of response. One group of students made active, verbal responses (multiple-choice options) to a visual presentation. A second group made visual responses (multiple-choice pictorial options) to a comparable visual presentation. While above average students profited more from responses to verbal options than to pictorial options, the reverse was true for below average students.

These findings in Study No. 2 showing an interaction between IQ and mode of response parallel the findings of this study showing an interaction between IQ and mode of stimulus presentation. Together they suggest that learning of abstract concepts in science (even when it is measured by verbal test items) becomes easier for below average students when it is based on concrete, *visual stimulus materials* and on concrete, *visual responses* to visual presentations. On the basis of the individual differences observed, programmed visual lessons in science appear to be less difficult than programmed verbal lessons. In support of this view additional data will now be reported that, unlike the data just reported, cut across ability levels.

Transfer from learning situation to testing situation. - It might generally be expected that transfer would be facilitated from the learning situation to the testing situation the greater their similarity (Hartman, 1961). Not surprising, therefore, is the finding that the solely visual experience (compared to the verbal experience) led to superior performance on *visual test items*. Nor was it surprising that the verbal lesson, consisting both of verbally described concrete examples and abstract statements, proved a more effective prior experience for the relatively more abstract, verbal items than it did for concrete pictorial items. While the verbal lesson did lead to successful performance on the *verbal test items*, it did *not* prove to be superior to the visual lesson in this regard. Experience with what of necessity had to consist of concrete, visual examples in the visual lesson allowed for successful transfer to either concrete, visual *or* to abstract, verbal test items.

Concept acquisition based on the experience provided in the programmed, solely visual lesson appears to have facilitated transfer to either a visual or a verbal criterion test. In contrast, concept acquisition based on a programmed verbal lesson appears to have facilitated transfer less readily to the visual criterion test than it did to the verbal test. It appears, on the basis of this difference in findings for visual and verbal lessons, that for transfer to occur, similarity between learning situation and testing situation may be less important when learning is based on visual (pictorial) materials.

The difference between performance on the visual criterion test and on the verbal criterion test does not appear to be due to differences in their difficulty levels. The difficulty levels for both the visual test and the verbal test, as revealed by average scores, were roughly the same. At the simplest descriptive level of explanation what does seem to be occurring is that concept learning based on concrete (visual) materials (as compared to concept learning based on abstract, verbal materials) is better able to facilitate transfer to a testing situation even though the testing situation involves a presentation mode different from that used in the learning situation. Thus, it appears to be easier to make the connection between visual experience and verbal description of it than it does to make the reverse connection. This would seem to be consistent with the everyday experience of the greater ease in attaching verbal labels to visually perceived objects and events than to visualize abstract, verbal statements.

Transfer from one learning situation to another. - The effectiveness of the visual presentation can be measured not only by the transfer effects it had on a subsequent testing situation but also by the transfer effects it had on a subsequent verbal learning experience. An effective integration of self-contained, programmed visual lessons and self-contained, programmed verbal lessons appears to have been achieved when the visual presentation preceded the verbal. As shown in the achievement results of Tables 5, 6, and 7, the visual/verbal order of presentation excelled the verbal/visual order. These findings are interpreted to mean that concepts are more readily acquired when responding to concrete, visual stimulus events is made to precede responding to more abstract, verbal events. Concepts were, it is true, acquired on the basis of the visual experience alone and apparently without difficulty. The more abstract and technical explanations embodying the concepts were, however, more readily and completely acquired from a verbal presentation when it followed rather than preceded the visual presentation.

This discussion has been based on achievement data obtained following both the visual and the verbal presentation. No separate measure was available for the verbal presentation (the second learning experience) that followed the visual presentation. Study No. 2, however, both replicates the findings of the superiority of the visual/verbal order and, in addition, provides a separate measure of the ease of learning during the verbal lesson. With "time-to-complete" the self-paced verbal lesson as the dependent measure, it was shown that students took less time to complete a verbal program when it followed rather than preceded a visual lesson. The data from both studies, thus, suggest the facilitating effect a programmed, visual presentation has on a subsequent verbal learning experience.

Summary

Three groups of findings have been presented each of which suggests advantages for the use of programmed, visual demonstrations. What can be said of the generality of these findings? The findings have been replicated in two separate studies with different science lessons. The applicability of these findings to other subject matter areas would appear to depend on whether or not the subject matters are, first of all, rich in principles and examples. Secondly, it might depend on the nature of the referents of visual examples. Do the examples refer to everyday objects and events or are they simply analogies for abstract ideas? Additionally, the applicability of the findings may be confined to an age group comparable to that of the eighth graders used in this study. In keeping with views about stages of development and the capacity for abstract thinking, the superiority of concrete experience for a still younger group appears a likely possibility (Ausubel, 1963). Whether the advantages of prior visual experience will hold true for older groups cannot as readily be predicted, and it therefore remains a question for further study. It might be hypothesized, however, that, for teaching ideas that are highly complex and that are new to a student, a student's age may be of little consequence when there are advantages to be had from the use of visual examples.

With these reservations in mind, what can be made of the three groups of findings just discussed? One group of findings suggests that below average students have an easier time learning concepts when it is based on discrimination practice with visual stimulus events and (in a study yet to be reported) with visual (pictorial) response options. A second group of findings suggests that when concepts are learned through discrimination practice with visual stimulus events, the similarity between learning situation and testing situation may not be, as is often the case, as important for transfer to occur. A third group of findings suggests that positive transfer effects from one learning situation to another are more likely to be obtained when learning based on a visual experience precedes learning from a verbal experience than when the reverse order is followed. Concept acquisition based on discrimination practice with visual events followed by the acquisition of the same concepts (but in technical language) based on verbal lessons appears to provide the makings of an effective instructional strategy. Based on all three groups of findings presented here, how are the advantages visuals seem to provide to be interpreted?

The results which require interpretation are these: why is visual experience easier than verbal experience (as evidenced by the fact that below average students tend to profit more from it than from the verbal experience); and why does visual experience tend to facilitate transfer across modes more readily than does verbal experience?

Difficulty Level of Visual Experience

(a) Due to everyday experience with shapes, colors, sizes, etc., responses to attributes of physical objects and events are generally at high strength. (See Gropper, 1963a, for a discussion of the generalized reinforcing properties of visual stimuli.) On the other hand, responses to verbal symbols for the same phenomena, or for abstract referents, are not likely to be at equally high strength. Because of these differences in response strength, the relative cue-value of visual and verbal examples are likely to differ. As a result, the appropriate discriminations and generalizations on which the acquisition of concepts depends, are apt to be more difficult when they are based on verbal rather than on visual examples.

(b) The objects or events in visual examples rarely consist of single attributes to which students must respond. More often than not they consist of such phenomena as: changes in attributes as, for example, a change in color or size; causal relations, as for example, an apparent loss of weight when an object is submerged; comparisons of attributes, as for example, the relative magnitude of the forces being applied at the two ends of a lever; long sequences of events, as for example, the assembly of coils in an electric motor; etc. Visual stimuli in science demonstrations are thus not single, simple stimuli, but often consist of dense patterns, complex combinations, or chains of stimuli. The more complex the patterns, the combinations, or the chains, the more difficult are responses to them apt to be. In connected discourse subject matter, science for example, verbal stimuli are also rarely single words; most often they consist of chains of words forming sentences of varying degrees of complexity. Response difficulty of sentences is thus likely to be greater than the response difficulty of single words. The question arises, "Is the visual 'sentence' then any less difficult than the verbal sentence?" It is assumed here that, because of the lesser difficulty level of the separate components of the visual, concrete "sentence," the complex of visual stimuli is likely to be still less difficult than the complex of verbal stimuli.

(c) The value of a stimulus for cuing a correct response is apt to be a function of how univocally stimulus and response are related. Verbal stimuli (words) are apt to have more associations than are visual stimuli and response competition, as a result, is therefore more apt to occur. The cue-value of verbal stimuli is thus likely to be less dependable.

(d) There is evidence from research on the concept learning process which suggests an explanation for the relative ease of the visual lessons (Bruner, et al., 1956). Bruner found that, when students are required on their own to arrive at a concept, it is easier for them to categorize attributes of phenomena than to verbalize the principle. Unlike traditional studies of concept learning in which concepts are arrived at inductively by the student without guidance (save for that provided by the definition of the task), induction of concepts in this study was guided. The task required of the student in the visual lesson was essentially a guided, categorizing task. Students were required to categorize pictorial options (portraying outcomes) as being the same as or different from outcomes they had already seen demonstrated. The task of the student in the verbal lesson however was, by definition, more highly verbal. Thus, the issue resolves itself into one of the relative difficulty of the two tasks: guided categorizing of physical attributes vs. guided verbalizing of principles concerning physical phenomena. Concept formation studies, like the Bruner study, suggest the lesser difficulty of the former task.

Transfer from visual to verbal experience. - The observed superiority of the visual/verbal order of presentation, as measured by achievement results in this study and latency data in Study No. 2, suggests a facilitating role for visual materials when they precede verbal materials covering the same concepts. There is evidence from research on paired-associate learning that an optimum condition is obtained when visuals are in the stimulus position and words in the response position (Lumsdaine, 1958; Kopstein & Roshal, 1954). Conflicting findings are also reported from other studies using different tasks (Bern, 1958). There is also evidence from research on procedural learning that prior visual familiarization with parts of equipment facilitates subsequent learning to select and use the parts (Jaspen, 1950; Wulff, 1954). The learning that occurred in this study, unlike that in the two sets of studies just mentioned, involved the acquisition of concepts, first on the basis of a solely visual lesson and then again on the basis of a purely verbal lesson. The technical language and the long verbal chains describing concepts appear to be better acquired when they follow rather than when they precede a visual demonstration. This appears to be not unlike the frequent experience in everyday life where words are learned for the concrete objects and events around us. Our experience of visualizing words is a much less frequent occurrence. One possible explanation of the superiority of the visual/verbal order of presentation in the classroom is that it capitalizes on a well established learning set.

Complex and highly abstract concepts and principles can be acquired on the basis of programmed, solely visual demonstrations. To rely on solely visual lessons for these purposes, however, results in marked inefficiency. This study attempted to test the limits of what could be done with a solely visual lesson. While it has been amply demonstrated that concepts in science can be learned from such lessons, it is also evident that considerable savings in time could have been had by even a moderate use of words during the presentation. Subsequent experience with programmed demonstrations has shown that, even if language is introduced, the advantages of a lesson using concrete, visual materials is not lost if the language used describes concretely, rather than explains, what is occurring (see Study No. 2). A single word, as has been aptly put, can be worth a thousand pictures.

Words serve an important cuing role when incorporated into a visual presentation. They serve other functions when they follow it. The data obtained in this study suggest that students can answer verbal items based on programmed, solely visual lessons. What a subsequent verbal experience appears to accomplish over and above this experience is the facilitation of longer verbal chains and the use of more sophisticated technical language to describe and explain the same phenomena. As educators, we may be content if students demonstrate mastery of concepts without the use of such technical language. Ultimately, however, it is probably more expedient and practical for them to master this language so that continuities and discontinuities among principles may be better understood and so that they can communicate with others. For these reasons, visual and verbal experience are perhaps best integrated or combined. On the basis of the results of the present study, a visual/verbal order appears to constitute an effective combination for this purpose.

STUDY No. 2: INTEGRATING VISUAL AND VERBAL PRESENTATIONS

PROBLEM

This study shares some of the objectives of Study No. 1. It is concerned with techniques for bringing responses under the control of a visual presentation and with instructional strategies for using visuals to teach verbal concepts. It differs from Study No. 1 in the following ways:

(1) Study No. 1 described programming techniques that were used to bring responses under the control of visual stimuli. To determine the generality of their effectiveness, it is important that their use be replicated with different lesson content. This study attempts to do so.

(2) Study No. 1 also was concerned with the optimal integration of visual and verbal presentations. An effective order observed was a visual/verbal order. But the presentations used in Study No. 1 were either solely visual or solely verbal and each was of considerable length. Thus, in addition to replicating the first study, this study is concerned with the segmenting of visual and verbal lessons into shorter, more practical units. Each shorter unit is concerned with separate concepts that interrelate to make up a larger, more complex body of concepts and principles. An optimum integration of these smaller visual and verbal units will be investigated.

(3) Study No. 1 employed visual presentations that had a fixed pace built into it. Verbal programs were also presented at a fixed pace. During both presentations the individual had no chance to adopt his own pace. This study is concerned with methods of integrating fixed-paced, visual lessons presented to groups and self-paced, verbal lessons in which the student can adopt his own pace.

(4) Study No. 1 was concerned with the relative effectiveness of visual and verbal modes of stimulus presentation. This study is concerned with the effectiveness of visual and verbal response modes during visual presentations. Pictorial response options will be compared with verbal response options. Results favoring pictorial response options may thus be able to complement the results favoring visual stimulus materials, with both forming the basis for an instructional strategy using visual materials to promote a verbal learning task.

The purpose of the present study is, therefore, both to replicate and extend the findings of the first study.

METHOD

Experimental Materials

Three experimental science lessons were developed for use in this study. Each was programmed and designed to develop student understanding of the concept "pressure." Two of the lessons were visual and were recorded on video tape. One called for multiple-choice responses to pictorial options. The second called for multiple-choice responses to verbal options. The third lesson was verbal, was reproduced in booklet form, and allowed students to proceed at their own pace.

Each of the three lessons was divided into five segments with corresponding segments in each lesson covering the same concepts. This made it possible for students to be exposed to a verbal and a visual lesson segment (in varying orders) covering the same concepts.

1. Visual lesson. - In Study No. 1, solely visual materials were used to cue responses; the only words used were those required to instruct students when and how to respond, but the words provided no cues as to what the correct responses might be. In this study, words were used. Once technical language (such as "force," "pressure," etc.) was introduced in a prior verbal segment, it was used in subsequent visual segments. However, these words were not used to make an abstract statement of a principle. Rather they were used to describe the concrete events or objects appearing on the screen. For example, the instructor might say, "Three lbs. of force is applied to this square, to this square, and to this square." Thus, greater flexibility was possible than was the case in Study No. 1. Language was used to cue responses, thus adding to the cue-value of the visuals. In addition, association of language and visuals was begun in the visual presentation itself.

Both visual lessons were programmed, required active responding to multiple-choice options, and generally were identical save for one feature. The verbal instructions and the demonstrated procedures occurring at each occasion for responding differed in the two versions. In version one, response options in booklets were pictorial, and the taped lesson generally demonstrated the options available. For example, the instructor might say, "If I don't want the paper to break, which way should I lay the block of wood down on it -- this way or this way? Put an X next to the picture showing the way the block should be if I don't want the paper to break." As he spoke these lines he demonstrated the two positions. The pictorial options appearing in the response booklets were identical with those demonstrated on the screen. The pictorial options that were presented in response booklets are reproduced in Appendix B for this study. In version two, which was identical to version one until this point, instructions for responding differed and went like this: "If I don't want the paper to break, which way should I lay the block of wood down on it -- standing on end or lying flat on its side? Put an X next to the answer which describes the way the block should be if I don't want the paper to break." The options in response booklets consisted, in this case, of phrases identical with the choices presented orally on the tape. The verbal options presented in response booklets are reproduced in Appendix B for this study. The two versions of the visual lesson, identical until the occasion provided for active responding, thus differed in the language and visuals used to cue responding (per se) and in the response option mode.

In the portions of the two tapes that were identical, carefully sequenced, repetitive demonstrations were presented. Their purpose was to enable students to make appropriate responses to incomplete demonstrations that followed. Appropriate responding depended on acquiring appropriate concepts based on the prior examples. Thus, prior examples were programmed to facilitate acquisition of the discriminations and generalizations relevant to each concept. This was done in each of the five separate segments of the lesson with the order of the segments so designed as to build to the concept of "pressure."

Each of the five segments was devoted to one or two concepts or one or two principles. The following descriptions and photographs taken during taping, rehearsals, and playback will illustrate the point.

Segment 1: This segment was designed to teach students that, because objects have weight, they exert a downward force on the objects on which they are resting and that the strength of the downward force depends on the weight of the object.

As shown in Figure 1, the weights of two objects were first compared on a balance scale.

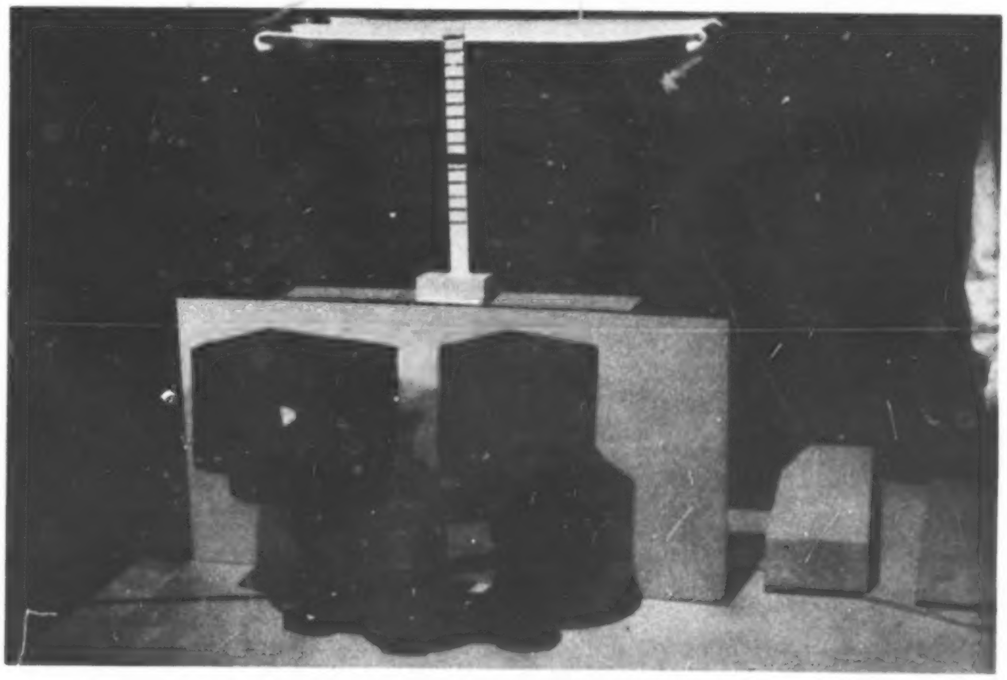


Figure 1

One object of the pair was then placed on a flexible rubber sheet to demonstrate the downward force it exerted. The problem posed to students was that of determining whether the second member of the pair would depress the rubber sheet as much as, less than, or more than the original member. As shown in Figures 2 and 3, the instructor first pointed out how far down the one member of a pair depressed the rubber sheet and then, allowing students easily to compare the relative sizes of the two objects, to predict the extent to which the larger of the two objects would depress the rubber sheet. In this fashion students acquired the

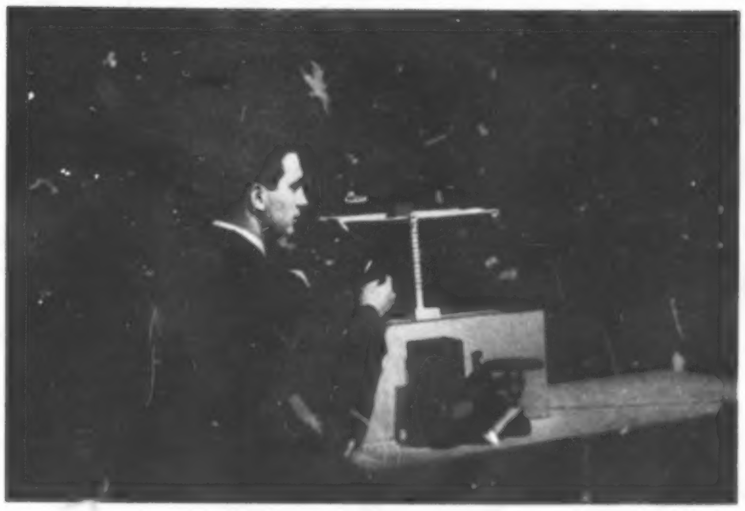


Figure 2

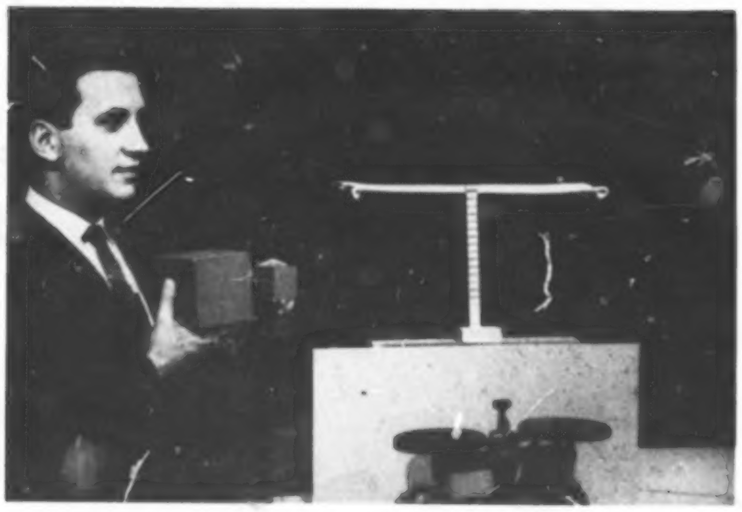


Figure 3

concept that the extent of the depression of the rubber sheet depended on the (size and) weight of the object.

Segment 2: In this segment, as shown in Figures 4 and 5, it was demonstrated that an object weighs the same no matter what position it is in.

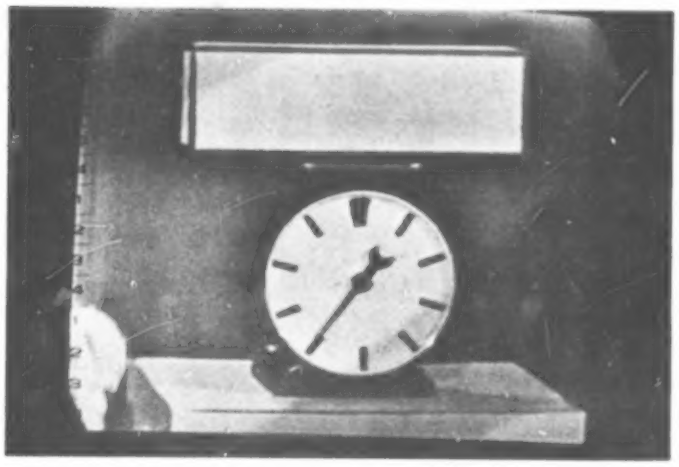


Figure 4

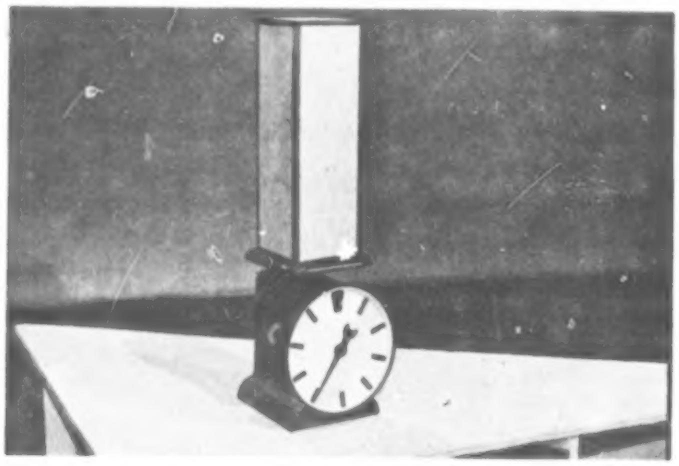


Figure 5

Students were then expected to predict the strength of the force of a different object in varying positions. Following that, as shown in

Figures 6, 7, and 8, it was demonstrated that the same force could be applied to a different number of spaces on a checkerboard, depending on the position of the object.

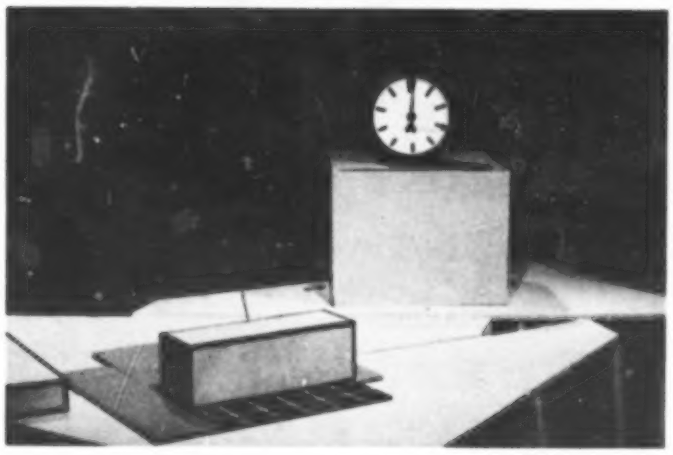


Figure 6

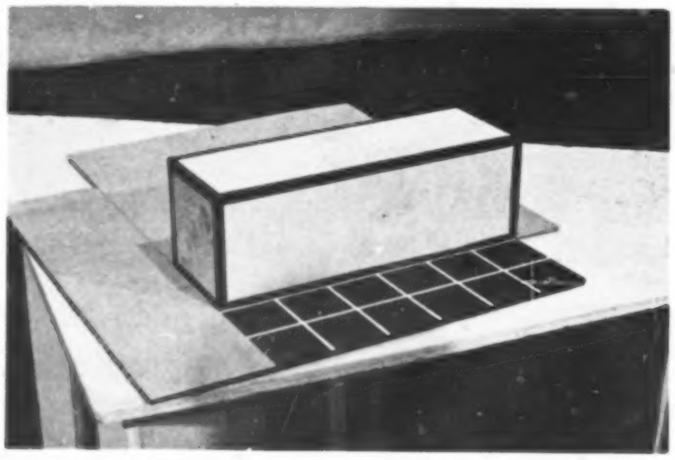


Figure 7

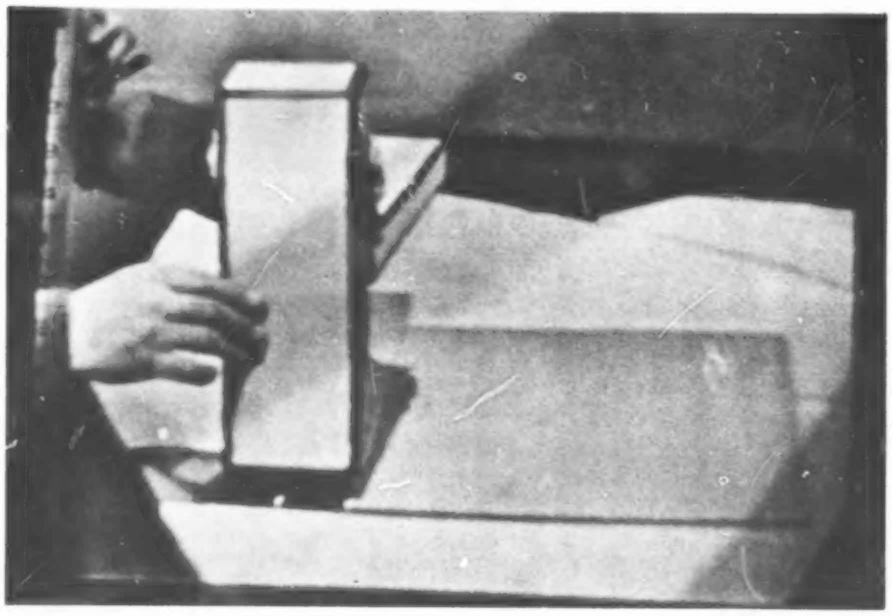


Figure 8

Segment 3: In segment three, as shown in Figures 9 and 10, it was demonstrated that a 12-lb. force (1 lb. for each cube) could be redistributed so that different amounts of force are applied to each checkerboard square.

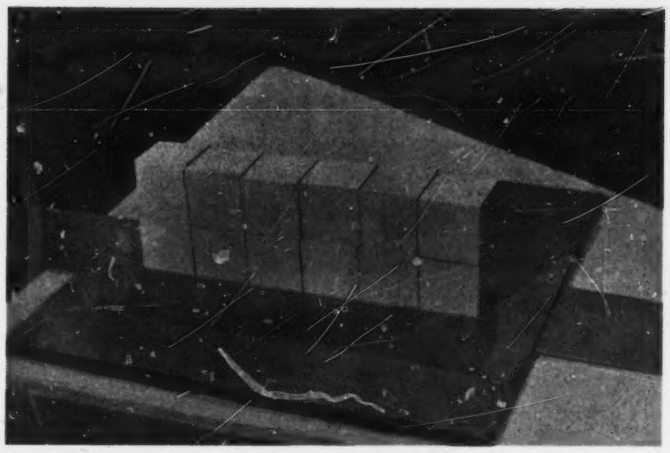


Figure 9

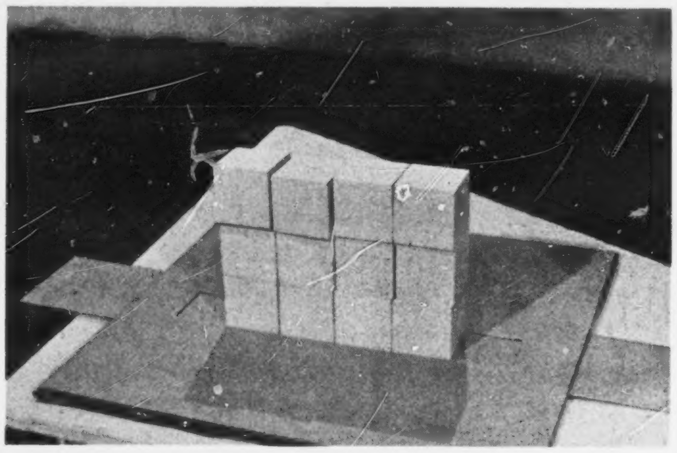


Figure 10

After seeing that a 2-lb. force was applied to each square, as in Figure 9, and a 3-lb. force was applied to each square, as in Figure 10, students were then asked to predict how the blocks should be rearranged to apply a 4-lb. force to each square. This kind of practice was designed to teach how much force was applied to each *unit* of a total area through the redistribution of a *total* force.

Segment 4: In segment four it was demonstrated, as in Figure 11, that the pressure on a piece of paper (and its likelihood of being torn) was increased as more blocks were added to the same pile.

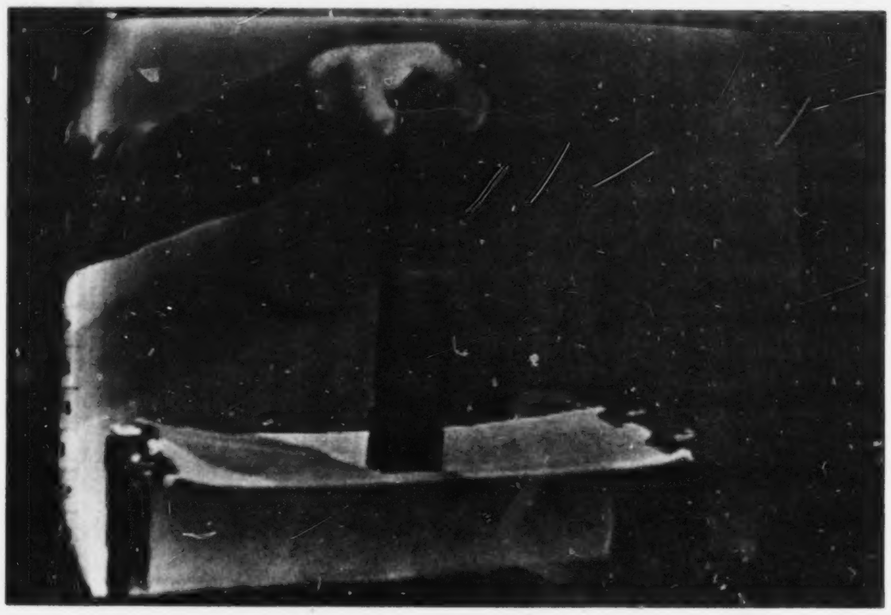


Figure 11

In addition, as shown in Figures 12, 13, and 14, it was demonstrated that the paper was more or less likely to break depending on how many piles were formed.

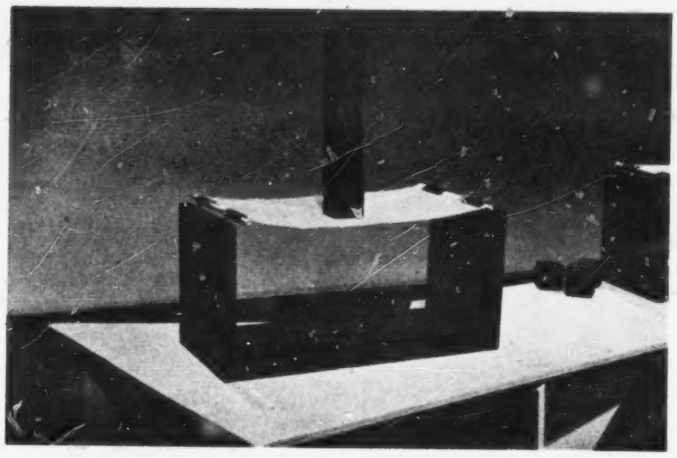


Figure 12

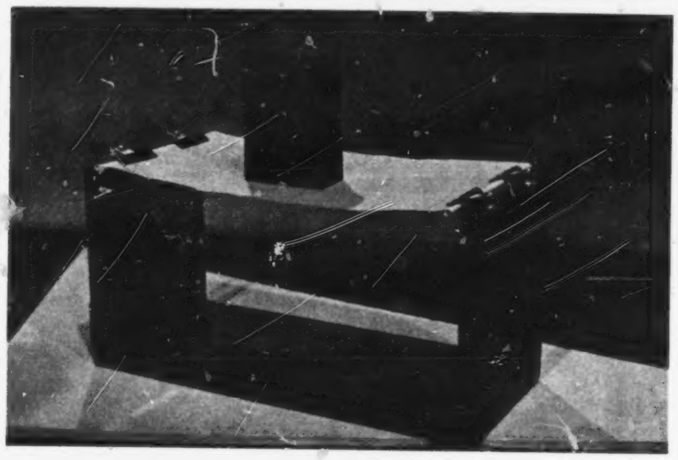


Figure 13

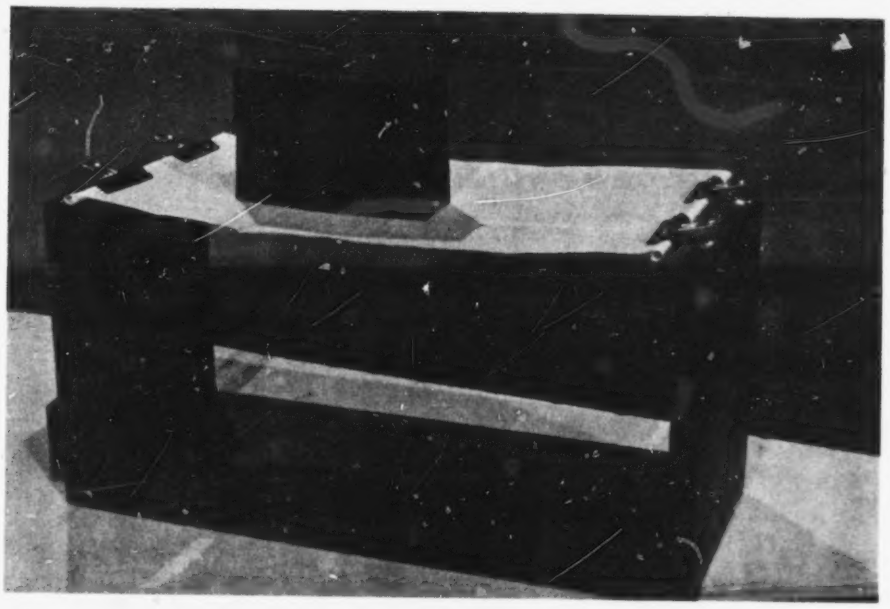


Figure 14

The problem posed to the student was that of predicting in what arrangement another set of blocks would create the greatest pressure and thus be most likely to tear the paper.

Segment 5: Segment 5 was concerned with the concept that the magnitude of the pressure exerted depended on the area over which a force was distributed. For this purpose, it was demonstrated that when the oblong shaped object was laid down on its side, the stretched piece of paper did not tear (as in Fig. 15).

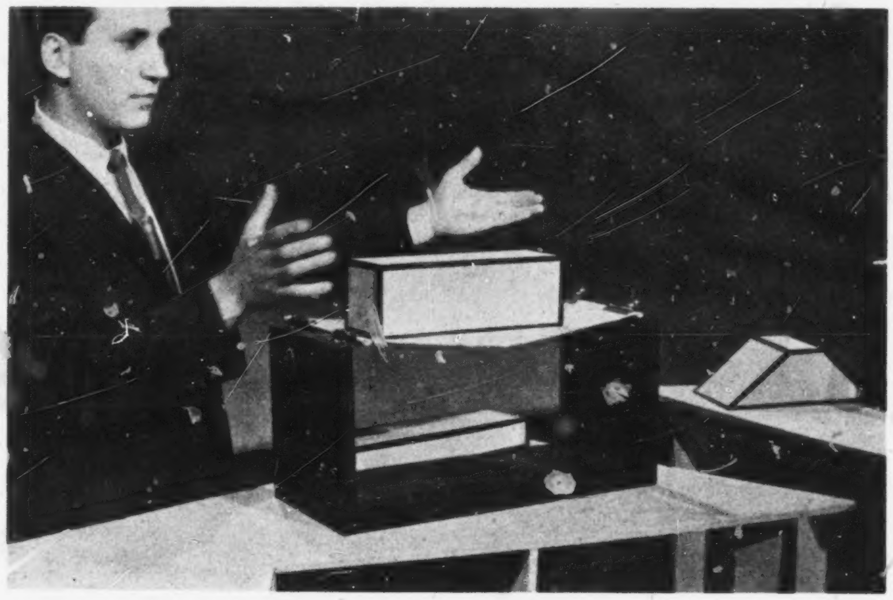


Figure 15

The paper did tear after the object was lowered in the position shown in Figure 16.

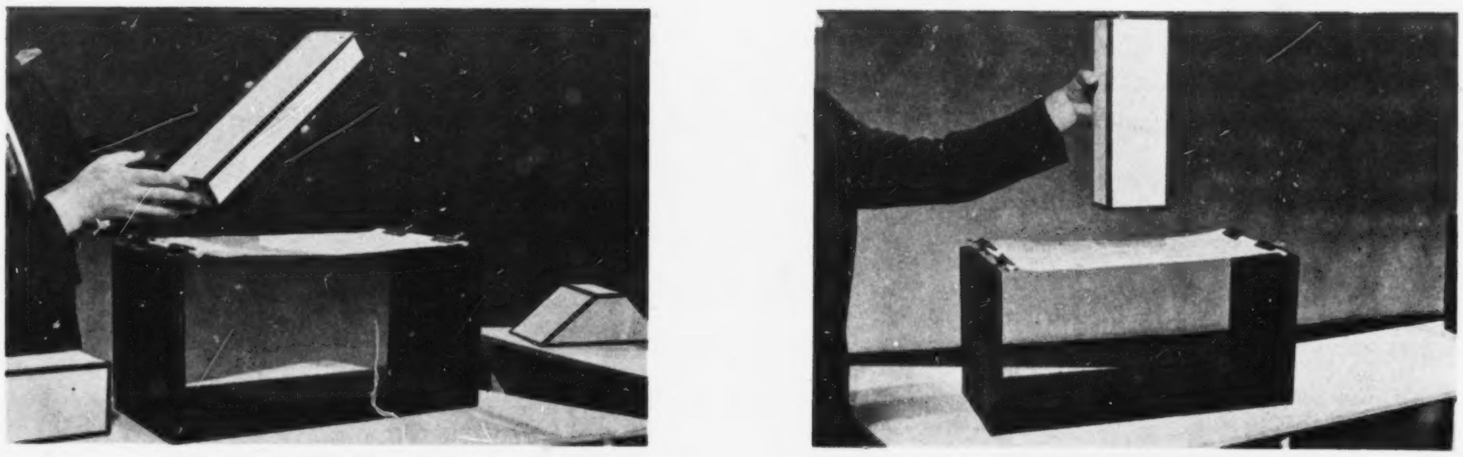


Figure 16

Following that, students were asked to predict in which position the object in Figure 16 should be laid if the paper were not to be torn. Additional practice was given with the object shown in Figures 17 and 18, with students required to predict that laying the object down on its large side would prevent the paper from breaking.

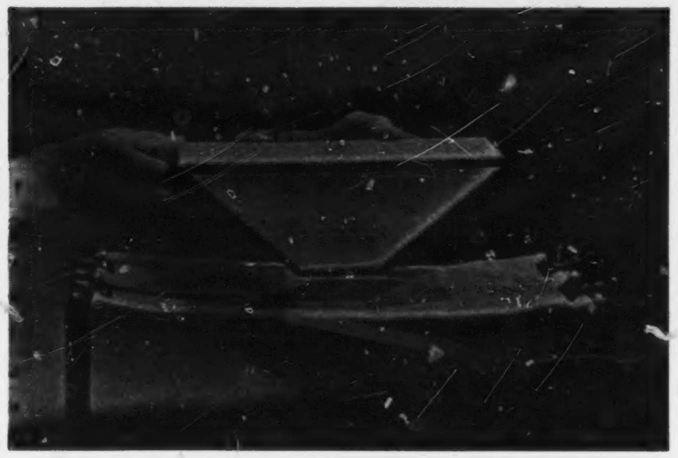


Figure 17

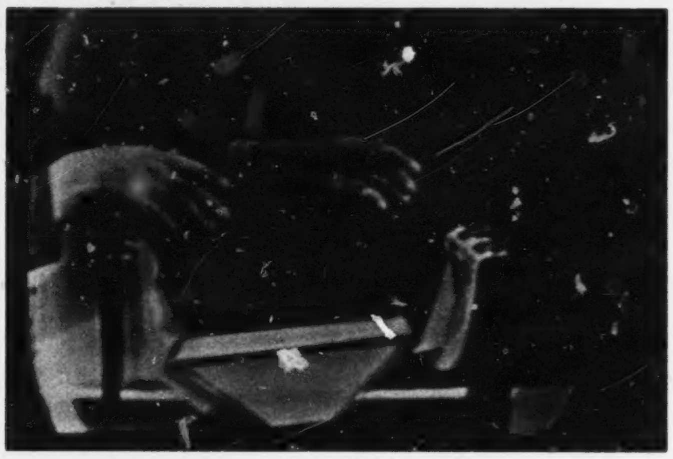


Figure 18

The two visual lessons were recorded on video tape and then tried out with trial subjects. Based on the evidence of low error rates to each of the 13 prediction problems put to them, the decision was made that it was not necessary to revise these lessons.

2. Verbal lesson. - A verbal lesson was prepared based on the same lesson objectives that guided the preparation of the visual lesson. In this case however, abstract statments of principles as well as concrete examples were included. The verbal lesson was broken up into five segments corresponding to the five segments of the visual lesson. The lesson was programmed, tried out, and revised until an error rate of 10% was achieved. The entire verbal lesson is reproduced in Appendix A for Study No. 2.

Design and Experimental Variables

The three experimental lessons were combined in various ways so as to bear on a number of research issues. Table 1 summarizes the experimental design and identifies the four treatment groups observed.

Table 1

Design of Experiment

	Group 1	Group 2	Group 3	Group 4
Presentation 1	visual lesson (pictorial response options)	visual lesson (verbal response options)	verbal lesson	verbal lesson
Presentation 2	verbal lesson	verbal lesson	visual lesson (pictorial response options)	visual lesson (verbal response options)

This design makes it possible to collect observations on these problems: (1) a comparison of the visual/verbal order vs. the verbal/visual order; and (2) a comparison of responses to pictorial options vs. responses to verbal options during the visual presentation. A comparison of results based on achievement tests administered before, immediately after the experimental session, and on a delayed basis provided answers to these questions. The achievement test used is reproduced in Appendix C for this study. It consisted of multiple-choice and constructed-response verbal items.

Subjects

Subjects were eighth grade students drawn from classes which regularly watched junior high school science televised over station WQED in Pittsburgh. Students were assigned at random to one of the four treatment conditions.

Procedure

A few weeks prior to the experimental session, achievement tests were administered in the schools to determine each student's prior level of knowledge. In addition, students received a preliminary program on "force," a concept necessary to the understanding of the concept, "pressure." Working on the preliminary program also introduced students to "programmed" materials and thus served to reduce their novelty value. The experimental treatments were administered in the studios of WQED on a single Saturday.

Visual lesson segments were shown over closed-circuit television. The verbal lesson segments were administered in individual workbooks. Depending on the treatment group to which he belonged, each student worked through visual and verbal lesson segments in either of the two orders of presentation. Alternating visual and verbal segments were worked through until all five segments were completed.

As each student completed work on each segment of the self-paced verbal programs, a proctor recorded the time the student took to complete that segment. Following the complete administration of all five segments, achievement tests were administered.

Approximately four weeks after the experimental session, the same achievement test was administered in the schools to obtain a measure of retention.

RESULTS

The principal experimental comparisons made in this study were between: (a) responses to multiple-choice pictorial options and to multiple-choice verbal options during the visual presentation; and (b) a visual/verbal and a verbal/visual order of presentation. Subjects were assigned at random to each of these four treatment conditions. In order to determine whether random assignment resulted in successful matching of subjects across treatment conditions, an analysis of variance was performed. As summarized in Tables 1, 2, and 3 in Appendix D for Study No. 2: there were no significant IQ differences between treatment groups; there were no significant differences between treatment groups in work rate (time-to-complete on the preliminary force program administered in the schools); nor were there significant pretest differences. On variables known to be related to the criterion variables, treatment groups were thus judged to be successfully matched.

Subjects in each of the four treatment groups worked on the verbal program at their own pace. Table 1 presents work rate means describing how long each of the four groups took to complete the verbal program.

Table 1

Work Rate Means on the Verbal Program
for Each Condition in the 2x2 Design
(in minutes)

	Order of Presentation		
Mode of Response	Visual/Verbal	Verbal/Visual	Combined
Pictorial Responses	43.0 (a)	46.7 (c)	44.8 (g)
Verbal Responses	47.1 (b)	47.5 (d)	47.3 (h)
Combined	45.1 (e)	47.1 (f)	

The letters (a), (b), (c) . . . etc. will appear in subsequent tables presenting results of comparisons of separate pairs of conditions.

As recorded in this table, it is apparent that the group that required the least amount of time to complete all five segments of the verbal program, was group (a). This group worked on segments of the verbal program only after it had seen the corresponding visual segment. This group also made pictorial rather than verbal responses during the visual presentation. Group (a) averaged 43 minutes on the verbal program (the total time on all five segments). As will be noted below, this mean time for group (a) differed significantly from that for groups (b) and (c).

Individual comparisons between orders of presentation and between modes of response follow.

Mode of Response

a. Work rate (time-to-complete). - Combining the results for the visual/verbal and verbal/visual orders of presentation in Table 1, it is apparent that group (g), those students who responded to the pictorial options during the visual presentation, took less time to complete the self-paced verbal program than the students in group (h) who responded to the verbal options. Table 2 contrasts the work rates adopted on the self-paced verbal program by subjects who made either pictorial responses or verbal responses during the visual presentation.

Table 2

A Comparison of "Work Rate" Means on the Verbal Program for Groups Making Pictorial and Verbal Responses During the Visual Presentation

Mode of Response	Mean "Work Rate" (in minutes)	S. D.	N
Pictorial Responses (g)	44.8	(5.47)	36
Verbal Responses (h)	47.3	(4.10)	36
Analysis of difference between groups	F=5.82* df=1/64		

*significance at the 5% level

For notation (g) and (h) see Table 1.

As will be noted, the difference between the two groups was significant. (The complete analysis of variance is summarized in Table 4 in Appendix D for Study No. 2.)

The data for groups (g) and (h), which combine the results for the two different orders of presentation, show significant difference between pictorial and verbal modes of responding. It will be noted in Table 1, however, that the most substantial contribution to this difference comes from Ss in the visual/verbal order of presentation. In this order of presentation the difference in work rate for the two response modes, groups (a) and (b), is sufficiently large so that the data combining orders of presentation still reaches statistical significance. For the visual/verbal order of presentation, the difference between group (a), the pictorial response group, and group (b), the verbal response group, is statistically significant as noted in Table 3.

Table 3

A Comparison of "Work Rate" Means
for Pictorial and Verbal Response Groups
(visual/verbal order of presentation only)

Mode of Response		Mean "Work Rate" (in minutes)	S. D.	N
Pictorial Responses	(a)	43.0	(4.89)	18
Verbal Responses	(b)	47.1	(3.82)	18
Analysis of difference between groups		F=7.69** df=1/32		

**significance at the 1% level

For notation (a) and (b) see Table 1.

The relevant analysis of variance appears in Table 5 in Appendix D for Study No. 2. Significant response mode differences, groups (c) and (d) do not occur in the verbal/visual order of presentation. Since, in this order, visual presentation follows the verbal program, it is not surprising that the mode of response to the visual presentation has no effect on the work rate adopted during the verbal program. Pictorial responses made during the visual presentation result in work rates on the verbal program shorter than those resulting from verbal responses made during a similar visual presentation only when the visual presentation precedes the verbal program.

b. Achievement data. - Achievement data parallel the work rate data. On an achievement test administered at the conclusion of both the fixed-paced visual and the self-paced verbal lessons, significant differences were also observed between response mode groups. These differences, like those for the time data just reported, held only for those subjects in the visual/verbal order of presentation. On the immediate posttest, the pictorial response group outperformed the verbal response group. Mean posttest scores are summarized in Table 4, with the relevant analysis of variance summarized in Table 6 in Appendix D for Study No. 2.

Table 4

A Comparison of Immediate Posttest Means
for Pictorial and Verbal Response Groups
(total test score possible = 58 points)

Mode of Response	Immediate Posttest Mean	S. D.	N
Pictorial Responses	29.2	(7.11)	18
Verbal Responses	24.3	(6.31)	18
Analysis of difference between groups	F=5.37* df=1/32		

*significance at the 5% level

On the delayed test, the mean score for the pictorial response group was 29.8 compared to 27.8 for the verbal response group. This difference was not statistically significant. However, a statistically significant interaction was observed between IQ and mode of response. The means for the high and low IQ subjects who were in the pictorial and verbal response groups are summarized in Table 5, with the relevant analysis of variance presented in Table 7 in Appendix D for Study No. 2.

Table 5

A Comparison of Delayed Test Scores for High and Low IQ Ss in the Pictorial and Verbal Response Groups

IQ	Mode of Response				t	df	p
	Pictorial		Verbal				
	Mean	S. D.	Mean	S. D.			
High	27.4	(5.96)	31.9	(6.61)	1.44	16	.18
Low	25.4	(9.68)	17.7	(5.06)	2.00	16	.06
Analysis of interaction					F=6.02* df=1/32		

*significance at the 5% level

High IQ Ss who responded (during the visual lesson) to verbal, multiple-choice options, scored higher than did a group which was matched in IQ but which responded to pictorial, multiple-choice options. The findings for low IQ Ss was the reverse of this. Subsequent, separate t-tests showed non-significant differences; the test for the low IQ Ss just falling short of the 5% level of confidence.

Order of Presentation

a. Work rate. - Table 6 summarizes the "work rate" means on the verbal programs for those Ss who either took each segment of the verbal program after each segment of the visual program or before it.

Table 6

A Comparison of "Work Rate" Means for Visual/Verbal and Verbal/Visual Groups on the Verbal Programs

Order of Presentation	Mean "Work Rate" (in minutes)	S. D.	N
visual/verbal (e)	45.1	(4.86)	36
verbal/visual (f)	47.1	(4.85)	36
Analysis of difference between groups	F=3.72 df=1/64		

For notation (e) and (f) see Table 1.

Combining the data from response mode groups in Table 1, it can be seen that subjects who participated in the visual/verbal order of presentation, group (e) took less time to complete the program than those Ss who participated in the verbal/visual order of presentation, group (f). For 1/64 degree of freedom, an F value of 4.00 is needed for significance at the 5% level. The obtained value was 3.72, thus falling short of the required value. Table 4 in Appendix D for Study No. 2 presents the entire analysis of variance results.

Since there were significant differences in work rate for the two modes of response, as noted earlier, an analysis was made of the two orders of presentation for each mode separately. Significant differences in work rate resulted only for the group that made pictorial responses. (For the verbal response group, the values of the means for the two orders of presentation were almost identical, groups (b) and (d) in Table 1.) As noted in Table 7, however, for Ss who made pictorial responses, the visual/verbal order, group (a), led to shorter time requirements than was the case for the verbal/visual order, group (c). The relevant analysis of variance is summarized in Table 8 in Appendix D for Study No. 2. Thus, the visual/verbal order of presentation excelled the reverse order only when Ss made responses to pictorial options during the visual presentation.

Table 7

A Comparison of "Work Rate" Means
for Visual/Verbal and Verbal/Visual Groups
on the Verbal Programs
(pictorial response group only)

Order of Presentation	Mean "Work Rate" (in minutes)	S. D.	N
visual/verbal (a)	43.0	(4.88)	18
verbal/visual (c)	46.7	(5.26)	18
Analysis of difference between groups	F=5.12* df=1/32		

*significance at the 5% level

For notation (a) and (c) see Table 1.

Since the visual/verbal order of presentation provided a learning experience, that is, the visual presentation, occurring prior to the verbal learning experience, it might be argued that students in this condition merely had an added opportunity to learn that students who received the reverse order did not have. Referring back to Table 1, it can be noted that group (b), a visual/verbal order of presentation, also had the same added opportunity to learn. However, the mean work rate for this group, a verbal response group, was no less than that for groups (c) and (d). Thus, merely having the added opportunity did not make a difference. It appears that the visual/verbal order of presentation is preferable to the reverse order, but only if pictorial responses are made. (Similarly, pictorial responses are preferable only in the visual/verbal order of presentation.)

b. Achievement data. - Analysis of achievement data revealed no significant differences favoring either the visual/verbal or the verbal/visual order of presentation.

DISCUSSION

This study has been concerned with an exploration of both administrative and instructional strategies involving the use of visual and verbal materials. While the administrative strategies were not studied through experimental comparisons of alternative treatments, their feasibility was demonstrated through their application in a practical context. The administrative strategies implemented in this study were: (a) the combination of fixed-paced and self-paced presentations; and (b) the integration of small units of visual and verbal materials. The instructional strategies were the subject of experimental comparisons. These included a comparison of: (a) a visual/verbal and a verbal/visual order of presentation; and (b) pictorial and verbal response modes used during a visual presentation.

Each of the two types of strategies will be discussed separately below.

ADMINISTRATIVE STRATEGIES

Integrating Self-Paced and Fixed-Paced Lesson Materials

One of the administrative problems that arises in the use of self-paced, programmed materials is occasioned by the variability in student completion times. Decisions must be made about what the early finishers are to do while their slower counterparts catch up. When fixed-paced, group presentations on film or TV tape are intermixed serially with self-paced programs, the problem of the early finisher is potentially more serious. Given the demonstrated stability of self-adopted work rates, the early finisher on one section of a self-paced lesson is likely to be an early finisher on other sections (Gropper & Kress, 1965). Thus, he would repeatedly have to wait for the rest of a class. Evidence from the present study, however, minimizes the seriousness of this potential problem.

The practical experience gained in this study, particularly with treatment condition (a) (visual/verbal order and pictorial responses), provides clues as to how the serial intermixing of fixed-paced and self-paced materials can lead to administrative and psychological advantages rather than disadvantages. After Ss in this treatment condition saw a brief, fixed-paced visual demonstration, they then went on to work on a brief, self-paced verbal program. Four of the five self-paced segments required mean times of less than ten minutes for completion. The four mean times in minutes were approximately 6, 6, 7, and 9 minutes. The standard deviation for each of the four segments was approximately one minute. Thus, in all four segments over 90% of the Ss (± 2 S.D.'s) finished within a range of four minutes of one another. Only on the fifth segment, which required a mean time of 14 minutes and in which the standard deviation approached two minutes, did the differences in completion times for slow and fast Ss become more sizeable. Had all five self-paced segments been run consecutively, the variability in completion times would have become substantial. The waiting period for the early finisher would have posed serious administrative problems. It is apparent, however, that, when self-paced lesson segments are kept small, the magnitude of the variability in completion times among Ss can be reduced to manageable proportions.

The serial intermixing of fixed-paced lesson segments and self-paced lesson segments tends to reduce the amount of time an early finisher on the self-paced materials must wait until slower counterparts catch up and he can begin again. The long wait that occurs when a long, total lesson is used (due to early finishers often being twice as fast as slow finishers) can be avoided. This is, of course, not necessarily to suggest that the intermixing of fixed-paced and self-paced instruction in group settings might not be required for other reasons. For example, whenever film or TV is called for by an instructional strategy, either can be offered in conjunction with self-paced instruction without undue and troublesome administrative delays being imposed on early finishers of the self-paced portions of a lesson. Thus, on the basis of the practical experience gained in this study, tentative guidelines are provided for the administration of fixed-paced and self-paced lessons in group settings.

Integrating Visual and Verbal Materials

It will be recalled that in Study No. 1, an entire verbal lesson was made to follow or to precede an entire visual presentation. In this study, visual and verbal lessons were segmented, and visual and verbal segments were intermixed serially. Thus, each segment type (visual or verbal) was worked on closer in time to its counterpart. For example, a visual segment demonstrated that an object weighed the same no matter what position it was in. The verbal segment that followed immediately also dealt with the same principle. Thus, each concept or each principle or a small number of them was taught by two segments, one in the visual and one in the verbal mode.

It will be remembered that the size of lesson segments was not one of the variables studied experimentally. Thus, while there is no experimental evidence to support the conclusion, it is plausible to argue that the closer in time lesson segments covering the same concepts are, the more effective they will be in teaching the concepts covered in them. The closer in time the verbal materials follow the visual demonstration, the easier is their acquisition likely to be. When a presentation in each mode covers the same limited number of concepts, positive transfer from one mode to the other is more likely to occur, since interference from new concepts is less likely to occur. Based on this assumption, it is suggested that visual and verbal presentations be intermixed serially, with each presentation segment in each mode devoted to one or, in any event, to a small number of facts or concepts.

In the present study the visual presentation was fixed-paced and the verbal presentation was self-paced. As noted in the previous discussion, this posed no bar to their effective integration. And, in fact, positive good may have come of it. It is reasonable to suggest, based on the evidence of its effective, practical implementation here, that it is administratively feasible to present both fixed-paced visual materials in group settings with each student responding to the presentation on cue and verbal materials also in group settings but with each student responding at his own pace.

INSTRUCTIONAL STRATEGIES

The principal dependent measure used in this study was "work rate" or "time-to-complete" the self-paced verbal materials. As noted above, previous research has shown work rate to be highly stable and presumably representing a habitual pattern (Kress & Gropper, 1964). With Ss in the various treatment groups successfully matched on the basis of estimates of habitual work rate, significant differences in work rate between groups following exposure to experimental treatments became all the more convincing. Both pictorial responding and a visual/verbal order of presentation resulted in shorter work rates than did verbal responding and a verbal/visual order of presentation, respectively. The magnitude of these differences, amounting in some instances to 10%, and their occurrence in spite of the apparent stability of work rate estimates, describe the measure of effectiveness accruing from the respective treatments.

Response Mode

Responses to pictorial options during a visual presentation resulted in shorter work rates and higher achievement than did responses to verbal options during a basically identical visual presentation. Two possible explanation for this finding suggest themselves. First, pictorial response options may be superior to verbal response options simply because they are in the same mode as the stimulus materials. Second, pictorial response options are less difficult than the more abstract, verbal response options. Either explanation would be more soundly affirmed by data comparing pictorial and verbal responses to a verbal presentation. This study did not investigate this latter issue. The findings it does present tentatively suggest the greater ease of pictorial responses. These parallel the findings of Study No. 1, which demonstrated the greater ease of learning from pictorial stimulus materials, particularly for lower ability students. Together, both studies suggest that the use of concrete, pictorial material both in the stimulus and response positions facilitates the acquisition of concepts. The facilitating role of visuals can further be seen from the superiority (as measured by work rate data) of the visual/verbal order of presentation.

Order of Presentation

Like Study No. 1, this study demonstrated that, when pictorial options are used, a visual/verbal order of presentation is preferable to the reverse order. When concepts are first acquired on the basis of discrimination practice involving pictorial responses to concrete, pictorial material, subsequent learning of the same concepts in verbal, technical terms is facilitated. This replication of findings suggests that visual learning is easier than and consequently should precede the more abstract and difficult verbal learning. Whatever other role visuals might play in instruction, one role they appear suited for is the reduction of the difficulty level in learning abstract concepts. Such a role might be required in some instances for those particular students who require it or in other instances across the board for all when the material to be learned is particularly complex and difficult.

The reader is referred to the discussion section of Study No. 1 for an interpretation of how visuals come to be particularly suited for this role. Whatever their interpretation might be, the findings of this study point to the recommendation that programmed science demonstrations be used prior to a verbal lesson covering the same material and that the response mode used during active responding to the demonstration be pictorial or visual.

GENERAL DISCUSSION

GENERAL DISCUSSION

EXPLANATORY MODELS FOR VISUAL INSTRUCTION

Even though there are obvious qualitative differences between pictorial and verbal modes of instruction, both share a common objective. By means of either mode, the educator seeks to create a learning experience that will bring about a change in behavior. Audio-visual specialists who have theorized about how such changes might be brought about have tended to adopt one of two approaches. One group has concentrated on the qualitative differences between words and pictures and has accordingly not seen fit to adapt learning theory models, available for describing verbal learning, for interpreting learning from pictures. This group has specifically developed communications or information models to account for learning from pictures. A second group has sought to de-emphasize the differences between words and pictures and to emphasize the similar roles they play in instruction. It has accordingly preached the applicability of available theories of learning to both (see Symposium edited by Meierhenry, 1961). This polarization of views is similar in some respects to that occurring in such recent developments in instruction as "programmed learning."

As Klaus (1965) points out, programming techniques tend to be either stimulus-centered or response-centered. The former tend to be almost exclusively concerned with the meaning, structure, or organization of stimulus materials. The latter are concerned primarily with responses and with the conditions, including the design of stimulus materials, that insure adequate response practice. The former tend to be either atheoretical or configurationist in viewpoint. The latter tend to be connectionist (S-R) in viewpoint. In the case of programmed instruction, the latter point of view, as measured by the number of adherents, tends to be dominant. In the case of audio-visual instruction, the polarization of audio-visual explanations tends to parallel that just noted, with one difference. The stimulus-centered (information or communications) point of view tends to dominate. Unlike the learning approach, which stresses the behavior to be changed and practice conditions for bringing such changes about, the stimulus-centered approach in audio-visual instruction tends to be primarily concerned with the design of the message.

Audio-visual research on procedural learning and on motor learning has, it is true, been interpreted by some within a behavioral, S-R framework (e.g., Miller, 1957; Sheffield & Maccoby, 1961). However, empirical research in connected-discourse subject matters presented by audio-visual means has generally been interpreted by most audio-visual specialists within the framework of an information or communications model; (see Travers, 1964 for a review of such research). Most theoretical discussions in the same area also have tended to be "information" or "message" based (e.g., Hoban, 1960).

Choice of either approach to account for learning from pictures makes a difference in how research on audio-visual instruction prospers, for it dictates: the kinds of explanations a model offers; the issues that are considered important and therefore investigated; and where it looks for its data. "Information" models lead to research on questions about: the redundancy of a message; the relevance of a message; the capacity of visual and verbal channels for transmitting the message; etc. Behavioral learning theories are more apt to be concerned with: the analytic and dimensional analysis of variables that promote the acquisition, retention, and transfer of specific behaviors; the effect of visual and verbal modes of stimulus presentation on the acquisition of discriminations, generalizations, or chains, which are often described as the basic processes in all learning (Gilbert, 1962); the effect these different modes might have on such varied learning tasks as problem solving, learning of concepts, acquiring perceptual-motor skills; etc. "Information" approaches tend to rely for data on end-of-instruction achievement tests. Behavioral approaches, in addition, tend to rely for data on responses made overtly, explicitly, and actively during visual presentation. Asking different questions, the two different models obviously produce and provide the practitioner with different practical answers.

It is also true that some audio-visual discussions have borrowed explanatory concepts and terminology from both an information and a behavioral framework. Thus, in a discussion of "communications" transmitted through either the audio or visual channel, such S-R learning theory considerations as generalization from learning situation to testing situation are invoked (Hartman, 1961). Or, "response practice" or participation may be stressed (Ryans, 1963) even though the basic model is an "information" model that has no integral principles to account for its need. What are the consequences of such eclecticism for the growth of audio-visual theory and practice?

The explanatory and predictive capabilities of a theory increase as its laws begin to encompass an increasingly larger range of phenomena. Practical problems in turn are more apt to be solved as theory grows and becomes more comprehensive. A resort to selective borrowing from more than one theory to account (ad hoc) for particular phenomena within audio-visual instruction, thus, is neither likely to serve the advancement of either learning theory or of information theory; nor is it likely to make their practical implementation more widely useful or successful.

At present, supported by considerable empirical research, behavior theory encompasses a large body of explanatory principles that can account for a broad range of behavioral changes. It is reasonable to expect that they can account for the changes that define learning from pictures. As Postman (1961) has pointed out, "the process of audio-visual education does not call for the formulation of special principles; it calls for the application and elaboration of the general laws of human learning." The present study, concerned with the learning of concepts through visual (pictorial) presentations, has accordingly attempted to limit the variables chosen for study to those stemming from a behavioral model and to interpret the results observed within such a framework. The rationale for taking this approach is based on the premise that learning theory provides the sturdiest foundation on which to base an interpretation of "learning from pictures."

The behavioral way of looking at learning requires that the process be treated analytically; that the responses to be shaped at any point during an audio-visual presentation (not just end-of-course performance on an achievement test) be identified specifically; that the stimuli that are effectively to elicit them also be specified; and that the conditions of the pairing of stimulus and response be identified and arranged systematically so that the acquisition, retention, and transfer of the desired behavior will be facilitated. Such is the prescription of a behavioral model. One consequence of the failure to make such precise specification, is the uncertainty as to what it is in our presentation that actually brings about a change in behavior. The prescription applies equally well to learning from words or from pictures.

A further practical requirement of a behavioral approach is the precise description of the behavior to be changed. This is generally referred to as a definition of objectives. Its execution is important for two reasons. A comprehensive statement of objectives is necessary in order to: (a) determine whether students actually can do what a learning experience was designed to teach them; and (b) formulate an instructional strategy for building a learning experience that will bring about desired behavioral changes.

The goals of instruction are quite varied and, while words or pictures might be suitable in one instructional strategy, they might not be in another. The goals or objectives of instruction might consist of, according to one taxonomy of behavioral objectives (Gagné, 1965), (a) identifications; (b) knowledge of principles; (c) following procedures; (d) making decisions; or (e) performing skilled perceptual motor acts. If a picture is truly worth a thousand words, is this value likely to be invariant for all these types of learning? Even within any given type of learning task is the value of pictures likely to be invariant? Thus, research on learning from pictures, as well as practical applications of audio-visual principles, must pay due, analytic attention to the various types of learning, to the specific behaviors to be shaped, and to the strategies that can accomplish these objectives.

The two studies undertaken in this project have adopted and extended the technology that has developed in programmed instruction (one behavioral model) to pictorial presentations. They have accordingly been concerned primarily with: (a) techniques for bringing specific responses under the control of specific visual stimuli; and (b) the use of visual stimuli possessing such control within the framework of an instructional strategy designed specifically for one kind of learning task: the acquisition of concepts and principles.

TECHNIQUES FOR PROGRAMMING VISUAL PRESENTATIONS

Achieving Stimulus Control

In keeping with the prescription of a programming model, visual presentations used in the two studies reported on here were designed to bring specific student responses under the control of specific visual stimuli. Upon presentation of such problems involving the weighing of objects in air and then in water (the stimulus), the student was expected to predict the outcome -- what the change in scale reading would be (the response); or when provided with an outcome as stimulus (the tearing of paper in a lesson on pressure) to indicate which way a wooden oblong would have to be deployed on the taut sheet of paper (the response). When such appropriate responses are indeed made to the stimulus materials, stimulus control is said to be achieved. To achieve stimulus control, steps were taken during the visual presentations to insure that the responses students made to the lesson were overt, explicit, and active.

(a) overt responses. - Research on programmed instruction, verbal or visual, has to date provided inconclusive evidence to support the superiority of overt responses (writing, talking, etc.) over covert responses (thinking, reading, etc.). Having students record overt responses, far from being a theoretical requirement, nevertheless does tend to have the practical outcome of inducing students to stick to the tasks given them and to refrain from occasional or from total omissions (Holland, 1965). Moreover, it provides the researcher with objective evidence, not only that the student responded, but that he responded either correctly or incorrectly. It also provides the student with the opportunity to compare his own response with the correct answer, whenever this is judged to be necessary.

Even though there may be no theoretical reason to expect (visual) stimulus control to be facilitated by overt rather than covert responding, for the practical reasons just enumerated, students in this study were required to record their responses in answer booklets.

(b) explicit responses. - An overt record provides explicit evidence that a specific response was made following the presentation of specified stimulus material. The explicitness of the stimulus-response relationship, serves to make the study of the process of how it arises more exact; but, as in the case of the overtness of responding, explicitness in itself does not appear to be a necessary condition for achieving stimulus control. Explicitness merely provides the researcher with empirical justification for asserting that stimulus control of specific responses has been established.

In the typical linear, verbal program consisting of two or three sentence frames, students are required to make an explicit response on cue to an explicit, circumscribed amount of stimulus material. It is virtually certain that, in addition to making the response to be practiced (the blank to be filled in), the student also makes other responses. It is fairly safe to assume that some of these other responses, particularly the reading responses he makes, are under the control of the circumscribed, printed stimulus materials. If the correct response is truly contingent on such prior or precursory reading behavior, our assumption becomes increasingly more cogent. Other responses, thinking, for example, cannot so explicitly be identified. However, by circumscribing stimulus content and hence the prior reading, observing, or problem solving behavior on which the response to be acquired is contingent, it is possible to reduce the probability of other non-explicitly identifiable responses being made. Whether or not these other responses, which despite our efforts to preclude their occurrence, actually impair performance can always be estimated from student performance. The effectiveness of the frame in bringing a response to be shaped under explicit stimulus control is available from the student's recorded performance. Whether or not other non-explicit responses are made, a correct response made on cue to the frame can be taken as evidence that explicit, precursory responses have been made and that the explicit response (required by program objectives) has been newly brought under the control of an explicit stimulus.

The visual "frame," consisting sometimes of the presentation of one or two demonstration examples before a response is required, generally lasts a few and, at times, several minutes. The opportunity for adventitious, non-explicit responding can thus be assumed to be greater than would be the case in a verbal frame. While the visual frame "lasts" longer than the verbal frame of one or two sentences, its content restriction can be similar. The complexity of the events to be observed can be kept minimal. The amount of stimulus (cuing) elements can be kept small and efforts made to eliminate the so-called enrichment elements. Further, student observing responses or attending behavior can be shaped or directed either through visual techniques (such as camera framing, the use of identifying symbols, etc.) or through verbal instructions. As in the case of reading behavior during work on verbal frames, we may be satisfied that these observing or attending behaviors are likely to be under the explicit control of the presentation (even if we have no observable record of them) if the response to be practiced is contingent on them.

One other class of non-overt responses may be under the explicit control of a visual presentation. Covert, mediating verbal responses to various stimulus features of the visual presentation are likely to be under explicit control. The responses most likely to be under explicit control are those responses that are at the highest strength. If attention can be specifically drawn to those features possessing such control, it is highly probable that, in addition to the attending or observing responses, mediating verbal responses will be made. The fact that they are made, may as was suggested earlier, facilitate generalization from visual learning experience either to a verbal learning experience or to a verbal testing experience. Thus although there is no concrete, overt evidence that such responses are under stimulus control, it is a likely assumption. While many other non-explicitly, non-identified perceptual and thinking responses, as suggested above, may also be occurring during a pictorial demonstration, specific techniques are available to decrease their probability and to increase the probability that specific responses will be made to specific elements of a presentation, particularly those responses that are made actively so that they may be brought under stimulus control.

(c) active responses. - Students viewing the visual presentation were required to make active responses. As defined in this study, this meant that they had to make anticipatory responses, responses made on the basis of cues varying in prompting strength. None were fully prompted, however. Having seen one example demonstrated, students might be required to predict the outcome of similar examples. To illustrate, in the lesson on pressure an oblong-shaped piece of wood was shown to tear a stretched out piece of paper when placed on it standing up on end and was shown not to tear it when placed on it lying down along its length. In a subsequent example, using an object similar in shape but differing in size, students were required to indicate which way it was to be placed on a piece of taut paper if the paper were not to be torn. The new object was highly similar to the first, differing from it only in size. The degree of prompting could be judged to be quite high (although short of complete prompting) in this instance. Another example using a trapezoidal-shaped object followed. Students were required to identify the side (the large side) that would not result in the paper tearing. Since similarity between it and the original example was reduced, prompting strength (based on the previous example) was also considerably reduced. Thus, the general procedure followed was to show one or more examples and then to require students to respond to a problem concerning one or more new examples. Responses came under the control of the relevant features of the presentation through such active practice. In the case of the example just cited, the generalization was learned that tearing of the taut paper depended on the area covered by the block of wood.

Response protocols and achievement data suggest that, by means of such "active" practice, responses were effectively brought under the control of the visual events and further that the instructional strategy employed facilitated the student learning task of acquiring the concepts and principles illustrated by the demonstrated examples.

Facilitating Student Learning Tasks

The learning task expected of students in this study was to acquire concepts and principles in science. Concept acquisition may be inferred from behavior indicating that a student can: (a) distinguish between classes of objects or events that possess given attributes and classes that do not; and (b) generalize to all applicable instances within a class (sometimes despite superficial dissimilarities) (Mechner, 1963). Thus a student must be able to correctly identify all instances shown him of "perfectly elastic" objects and to identify those that are "not perfectly elastic." Principles generally consist of relationships among two or more concepts, as for example, in the statement that "when a stress is removed, a perfectly elastic object will return to its original shape." Instruction in science, whether through verbal or visual means, is replete with the teaching of such concepts and principles.

Traditional studies on concept formation (see Bruner, et al., 1956, for example), are concerned with conjunctive concepts (two or more attributes jointly define the concept), disjunctive concepts (one or another attribute defines the concept), or relational concepts (relations among attributes). Concepts and principles in science can be identified as belonging to one or more of these classes. But, the study of how such concepts are acquired in traditional investigations and in investigations involving programmed teaching of concepts is markedly different.

Traditional concept formation studies are concerned with how a student on his own inductively arrives at a concept. Concept acquisition is contingent on the precursory or ancillary behavior of testing hypotheses about attributes that unify a class of objects or events. In marked contrast to this, the precursory behavior in programmed instruction (visual or verbal) consists of reading, observing, or problem solving behavior. Such behavior is guided by the stimulus materials presented to the student. In the visual presentations used in this study, concepts were, it is true, also arrived at inductively, but the process was guided by the series of examples presented. The acquisition of the discriminations and generalizations underlying concepts and principles was systematically built up through active responses to a programmed sequence of visual examples.

In view of the decided differences in the precursory behavior that mediates the acquisition of concepts in traditional concept formation studies (hypothesis testing) and in programming studies (observing, reading, problem solving), it is reasonable to question the applicability of results of traditional studies to programming applications. If, for example, traditional concept studies show the overall superiority of using all positive examples (to either the use of all negative or the use of positive and negative examples), do such findings also apply to programmed sequences designed to teach concepts? Even if the type of concepts being taught (conjunctive, disjunctive, or relational) are the same, principles that show how hypothesis testing behavior is facilitated may not be the principles that apply equally well to the programmed learning experience. This point may be summed up by raising the question of whether studies of a process occurring naturally (concept formation based on hypothesis testing) provides appropriate guidelines for the design of an, as it were, artificial process developed to facilitate arrival at the same terminal behavior (concept formation).

The remainder of this section is devoted to a description of the learning experience based on visual stimuli that was devised to teach the discriminations and generalizations underlying the concepts to be taught in the two studies being reported.

(a) discriminations. - Learning concepts in science (or the relationships between concepts we define as principles) depends on acquiring discriminations between sets of conditions, generally two sets of conditions. For example, an object will start to move if a force is applied to it. It will remain at rest if a force is not applied to it. The student must learn to distinguish between the consequences of a "yes" condition (a force is applied) and of a "no" condition (no force is applied). He must also learn to distinguish between the consequences of an "a" condition and a "b" condition with "b" being a condition other than "a" and not merely the absence of "a," as in the yes-no situation. An object weighed in air ("a") will weigh more than the same object weighed in water ("b"). Or, an object placed on a taut piece of paper is more likely to tear it if set down on its end (small area - "a") than if it is set down on its side (large area - "b"). In this "pressure" example, the discrimination might be about the alternative consequences of different placement positions.

Concepts are not restricted to binary conditions. In electronics, for example, the resistance values of resistors are color coded, with each of 10 values assigned a different value. Students must learn to discriminate among all 10 colors and apply the appropriate value to each. Science principles and concepts can, however, generally be accounted for by the binary situation.

In this study, to build up the yes/no or a/b discrimination, contrasting visual examples were presented to the student. He first saw the scale reading of the object weighed in air and then saw the changed reading when the object was immersed in water. He saw the oblong laid on its side resting on a taut piece of paper and then saw the paper tear when it was deposited on the paper on its end. Or, as in other studies using the same procedures, he saw stressed objects return to their original shape (perfectly elastic objects) and then other objects remain distorted (non-perfectly elastic objects).

Although there is no experimental evidence from research in programmed instruction bearing on the problem, it is reasonable to suppose that presentation of contrasting visual examples simultaneously or in immediate succession would be superior to a series of positive examples followed by a series of negative examples (or vice versa). (There is, it should be pointed out, research on concept formation which supports the opposite view. This research was generally concerned, as pointed out earlier, with the strategies subjects adopt themselves in arriving at a concept. The current research was concerned with instructional strategies for guiding the subject to arrive at a concept. Differences between these learning tasks employed may account for the differences in positions taken here and in other traditional concept formation studies.) Contrasting examples, whether simultaneously presented or in quick succession, it is suggested, helps the student to differentiate or discriminate between the "yes" and the "no," the "a" and the "b." Simultaneous contrasts would seem to be best reserved for static visuals. Before and after representation of a non-perfectly elastic object (before stress is applied and after it is removed) might be one such simultaneous contrast. Or, pictures of or diagrams of the different classes of levers might be similarly presented. When on-going demonstrations are to be contrasted, however, interference between "a" and "b" is perhaps less likely to occur if they are presented successively. Particularly when the same physical object is to produce different results, successive presentation seems indicated. In this study, the same block of wood was placed on a taut sheet of paper in two different positions -- with two different consequences. They were contrasted one right after the other. However, only with the availability of a full catalogue of types of discriminations to be made about physical objects used in science demonstrations can principles be developed concerning the range of conditions in which positive and negative instances and in which "a" and "b" instances might best be presented simultaneously or consecutively.

(b) generalizations. - The decision as to how best to facilitate acquisition of discriminations concerning attributes of physical objects or events is further complicated by the need to facilitate the acquisition of generalizations. The student, in addition to learning to respond differently to the "yes" and "no" conditions or to the "a" and "b" conditions, must also learn to respond similarly to all instances within the "yes" class, for example. He must be able to respond with the label "perfectly elastic" to all examples of objects which return to their original shape after a stress is removed (e.g., a rubber ball, a spring, a sponge, etc.). The problem arises, then, of deciding should all "yes" examples be shown first (to teach the generalization -- perfectly elastic) before the "no" examples are then shown (to teach the discrimination perfectly elastic vs. non-perfectly elastic). Which is the better strategy remains to be determined empirically by future research. The strategy used in this study and other studies was to present successive, repetitive contrasting examples as a means of teaching both the discriminations and generalizations. Thus, each contrasting example in a study yet to be reported served to build the appropriate discrimination (between what is perfectly elastic and what is not). Each successive example served to build the generalization (what is the range of objects that can be described as perfectly elastic and what is the range of objects than can be described as not perfectly elastic).

Thus the overall instructional strategy called for concepts to be taught through the presentation of visual examples suitably programmed so as to facilitate the acquisition of discriminations and generalizations. Stimulus materials were designed with this goal in mind.

Design of Stimulus Conditions

In order for a visual presentation (or any presentation for that matter) to prepare the student for criterion performance, it must be able to do two things: it must insure that the student attends to the relevant dimensions of the stimulus and then responds appropriately to it. The stimulus conditions that were (or can be) used to accomplish both goals will be described now.

(a) drawing attention to relevant stimulus dimensions. - Before we can elicit student practice of appropriate responses to the relevant dimensions of a stimulus, for example, the area of one side of a wooden oblong rather than the position of the oblong, his attention must be drawn to that dimension. This is true whether the instructional mode is verbal or pictorial. In verbal frames, for example, it is sometimes necessary to draw attention to key words. Underlining or italics sometimes are used to serve this purpose. Or, if it is important that students pay attention to a key distinction, the contrasting elements may be pitted against one another in multiple-choice options. Key, relevant dimensions are thus called attention to in various ways. The penalty for not doing so may be attention to an irrelevant stimulus dimension.

The problem of attention to irrelevant stimulus dimensions is no less insistent in visual presentations. Lacking the restricting qualities that grammar and sentence structure have, a visual presentation may elicit responses to any one of its multiple physical attributes. Attention must be limited to those attributes relevant to the concepts and principles being taught. Numerous "pointing" strategies are available for this purpose.

A concrete example may, perhaps, better illustrate how attention may be drawn to particular stimulus dimensions. The example of the wooden oblong laid on a piece of taut paper either on its end or on its side will do. The relevant dimension is "area covered" by the wooden oblong (and its relation to whether or not the paper tears). Attention to this dimension (and distracting attention away from the potentially competing dimensions) may be accomplished by: (a) verbal techniques (e.g., "watch what happens when I put the block down on its small side and when I put it down on its large side"); (b) physical pointing (either actual pointing or coloring of objects or parts of objects) ("watch what happens when the block covers this much of the paper" - traces the area, etc.); (c) camera techniques (not so relevant to the present example, but it is useful in that it can frame only relevant dimensions or at least reducing the number of dimensions that can compete for the students' attention); (d) action techniques (in a static visual containing many stimulus dimensions, unless one or another achieve perceptual dominance either because of color or foreground or background factors, no one feature will systematically draw attention); action visuals have the capacity to draw such attention (as for example weighing an object in air and then in water; the action is likely to win out over the depth of water in the tank or other static properties of the scene); and (e) response options (when the student is provided with multiple-choice options from which he can select a correct answer, the options serve to prompt the correct response. At the same time, they also limit the stimulus dimensions to which the student's attention is drawn. Thus, when the question is asked, "which way shall I place the block down - this way (on end) or this way (on side)," the alternatives suggest that it is not color, not height, not texture, etc. that is important. It suggests position or area.

By whatever means, it is important that attention be drawn to a relevant stimulus dimension so that a response can be brought under its control or so that it may elicit a response already under its control.

(b) prompting appropriate responses. - Although the objectives of the visual and verbal presentation used in this study were identical, i.e., to bring responses under the control of specific stimuli, most features of program design were different. As in most linear, constructed response verbal programs, the verbal lessons consisted of a large number of short frames, with each frame containing one or two sentences and with an overt, active response required on each frame; a gradual progression was observed with longer and more complex responses required as cues were gradually weakened or faded. The programmed visual presentation in contrast consisted of: a little more than a dozen responses in the whole program; multiple examples to which no overt, active responses were required preceded each response; the responses made were multiple-choice responses prompted by pictorial options; no fading of cues was used (each response was contingent on the precursory behavior of watching one or more prior examples), so that in essence each response was a criterion response.

Although there was no vanishing or fading of cues, cuing strength was sytematically manipulated. This was done through the number of prior examples shown. Judgments as to the difficulty of the concept to be acquired determined how many examples were shown before the student was required to respond. In the case of the oblong laid on the taut sheet of paper, only one example preceded the requirement that students respond to a similar problem with a different sized oblong. One additional example requiring a response (a trapezoidal-shaped piece of wood) was used since variety of examples was needed to teach the relationship between "area" and "pressure." (As a matter of hindsight, it is easy to see that the use of a cube, with equal areas on all sides, would have been effective in disabusing the idea that it was the position of the objects and not the area that was the relevant dimension.)

Difficulty of responding was also manipulated by the use of multiple-choice responding (rather than constructed responding). The number of options and option content was also manipulated to influence response difficulty.

Following each active response, a demonstration was carried out or completed and provided students with confirmation as to the correctness of their responses.

Summary

The visual programs used in the two studies may be described as follows:

1. Concrete examples capable of eliciting high probability responses were used.
    - 1a. When language was used during the visual presentation, its function was to describe in concrete terms what was going on; it did not explain or interpret.
2. Concepts or principles were acquired on the basis of an inductive sequence of examples.
    - 2a. Although inductive, the sequence provided guided experience in acquiring the concepts.
    - 2b. The response task was not to verbalize the principle once formed; rather it was to make predictions about events. Essentially the task was to categorize the outcomes or antecedents of events as being similar or different from those just demonstrated.
3. As in Study No. 2, a visual segment was designed to teach a single concept by means of the visual program and to be followed by a counterpart verbal program covering the same concept. (This can be conceived of as a paradigm for the use of the single concept film or for fully integrated films or television lessons.)
4. Within each segment only one or two responses were made; they were criterion responses (even though they were in the multiple-choice format) made without any immediate cuing; the only cuing derived from preceding repetitive examples.

4a. Concepts were acquired on the basis of the precursory or mediating behavior of merely watching one or more examples (with verbal mediation likely) and then responding to one or more (rarely more than three) examples, with responses contingent on the precursory behavior.

5. Discriminations underlying the concepts or principles were taught by the use of contrasting examples (e.g., the weight of an object in air and in water) and by the use of response contrasts (multiple-choice pictorial options).

6. The generalizations underlying the concepts derived from the use of at least two examples and, as necessary, variety in the use of examples.

The experience was concrete, guided, inductive, and repetitive. Concepts and principles were learned on the basis of just such a visual experience. Conclusions drawn about the value of visuals or about their value relative to words should be restricted to the type of programmed visual experience described here.

INSTRUCTIONAL STRATEGIES INVOLVING VISUALS

Visual demonstrations were used in the two studies described in this report to meet one particular type of instructional objective, namely, to teach student understanding of science concepts and principles. Students were, for example, expected to be able to define the term "pressure" or to compute the amount of pressure exerted or to state what the relationship between "force" and "pressure" was. The visual presentations were designed to implement an instructional strategy suitable for this objective. Had the instructional objective been different, say, to teach students how to make observations during the conduct of an experiment or to recognize examples in nature illustrating the principle being taught or how to perform the same experiments being demonstrated, other demonstrations would have been prepared and other responses to them practiced as called for by the strategy suitable for these differing objectives.

What role can visuals play in a strategy employed specifically for teaching concepts and principles? To see how visuals might fit in an instructional strategy suitable for this purpose, some general comments on strategy formulation may be helpful.

General Comments About Instructional Strategies

When instructional objectives are adequately stated, they include a specification of: (a) end-of-course stimulus contexts under whose control responses are to be brought, e.g., a student being able to provide a definition in response to the verbal question -- "what do we mean by pressure" and (b) the response (or classes of responses) to be made, e.g., "pressure = force divided by area." Suitable instructional strategies must specify the kind of learning experience that will lead to the fulfillment of such objectives.

The general aim of an instructional strategy is to create the kind of learning experience that will ultimately lead to the criterion performance either on a test or beyond the classroom as called for by instructional objectives. Strategy formulation might be based on the assumption that the transfer of learned responses from the learning situation to the criterion situation, would be expected to be optimally facilitated the more closely the two situations are alike. That this is not an invariant condition, however, is amply attested to by data from the present study, i.e., pictorial responses to pictorial stimuli facilitated student performance on a criterion test that contained verbal test items calling for verbal responses. Criterion performance in the learning situation and criterion performance beyond the classroom may thus vary from virtual identity to non-identity. The nature of these variations will be explored below.

What prescription for lesson construction must a strategy provide? To meet instructional objectives, strategies involving either words or pictures must specify: (a) the stimulus contexts in the "learning situation" under whose control responses are to be brought; (b) the responses to be brought under control; and (c) the conditions and techniques for bringing such control about. Decisions about each of these three sets of specifications are based on the assumption that successful performance in the particular kind of learning situation devised will facilitate successful criterion performance beyond the classroom. This assumption holds whether stimulus contexts used in the learning setting and the responses practiced are identical with those in the criterion situation or whether they differed markedly from each other.

(a) stimulus contexts. - The anticipated outcome of a learning experience is that responses come under the control of a simple stimulus or classes of stimuli (in whatever mode). In the case of concept learning, this means that students learn to make the same response to equivalent classes of stimuli. The driver learns to stop at all red lights or to signs that read "stop" or to a policeman's signal. Or the student can respond on a test indicating that he has learned that objects weigh less in water than in air, no matter what their shape or size. He can do this whether the test item is presented pictorially or verbally. These are criterion performance outcomes (on a test or outside the classroom) resulting from a learning experience in the classroom.

Criterion performance, in the case of concept learning, consists of one of a class of functionally equivalent responses in the presence of one of a class of functionally equivalent stimuli. To be capable of such a criterion performance the student must practice the same or functionally equivalent responses in the presence of a functionally equivalent context provided in the classroom. The learning context may be identical with the criterion context, for example, responding to a program item requiring a written definition of the word "pressure." It might be substitute context, possibly bearing some measure of similarity to the criterion context (e.g., everyday language used instead of technical language). Or it might be qualitatively different from the criterion context. It might, for example, be visual demonstrations of "pressure" phenomena (e.g., the same total force, as represented by a given number of blocks, distributed over different areas), even though the criterion performance is a verbal test (as was the case in this study).

Stimulus contexts in the learning situation and in the criterion situation can differ in terms of: (1) the modality in which they are presented; for example, pictures used in the learning situation when words or symbols constitute the criterion situation (e.g., the number line used to teach addition and subtraction of positive and negative numbers) or the converse; (2) the fidelity with which one reproduces the other (within the same modality); for example, a real object represented by a model in the learning situation; or (3) the comprehensiveness with which learning situation samples the elements of a criterion context.

Because it is desirable that transfer from learning situation to criterion situation be optimally facilitated, emphasis might therefore be duly placed on achieving maximal similarity between the two situations. Accordingly a strategy might call for use of a learning context similar to that in the criterion situation. As exemplified by the case of visual contexts used in the present studies, other considerations might enter. Some of these other reasons for selecting a visual learning context, even though the criterion context is verbal, will be detailed in a succeeding section.

(b) responses. - The distinction between "criterion" and "learning" situations applied to stimulus contexts under whose control responses are to be brought applies as well to responses. Responses made in the learning situation may vary from identity to non-identity with the responses to be made in the criterion situation. Differences between the two situations may be a function either of: (1) the topography or locus of a response (for example, practicing a verbal response when the criterion performance requires a non-verbal motor response); (2) the mode of response (for example, practice in recognition of a correct response when construction of a response is the goal); or (3) the response task posed the learner; (for example, in the learning situation, the learner's task might be to construct a sentence, whereas in the criterion situation, his task might be to complete a sentence; or in the learning situation his task might be to evaluate the correctness of someone else's performance as a means of preparing him subsequently to engage in it himself).

Responses selected for practice in the learning situation (however different they may be from the criterion response), must be capable of resulting in criterion performance. In the present study, multiple-choice responding to pictorial options resulted in a criterion performance consisting of responses to test items representing a range of response types including pictorial, verbal, multiple-choice, and constructed responses. Thus, it is apparent that the response practice devised in this study facilitated transfer across modes such that students were prepared for the specified criterion performance. A rationale for a strategy calling for the use of pictorial responses during learning even though criterion responses were verbal, will be offered in a succeeding section.

(c) conditions and techniques for gaining response control. - The ultimate objective of a strategy is to bring criterion responses under the control of criterion contexts. The strategy first specifies the learning contexts and the learning responses, which are judged capable of producing the end-of-course criterion performance. Not only are stimulus contexts specified, but stimuli that are used merely to produce responses are also specified. For example, a visual stimulus may be employed, not because we wish responses to be brought under its control (thus serving as a context). Rather it may already possess such control and we may wish control to be transferred from it to other stimuli. In this capacity it serves only as a cue. Thus, in its role as a cue a visual may be used to facilitate transfer of control to some other stimulus. Strategy considerations in selecting visuals for this role would involve their capacity, relative to that of verbal cues, for example, for cuing particular responses. It is apparent, therefore, that strategies must specify not only criterion learning contexts and responses but also all other learning responses and stimulus cues on which criterion learning performance is contingent.

Other strategy specifications would include a description of the conditions under which learning responses are brought under the control of learning contexts so that criterion performance is indeed assured. Specifications of conditions of response practice that can bring this about include a determination of: prompting strength at various stages of learning; amount of distribution of practice; how the acquisition of necessary discriminations and generalizations can be facilitated, etc.

It is apparent that criterion performance in the learning situation and criterion performance at the end of the course (whether on a test or on the job) may differ either with respect to stimulus contexts or with respect to responses. However different they may be, the strategy calling for a particular learning experience is designed in such a way as to bring about criterion performance whether on a test or beyond the classroom or training setting.

As revealed by the data of the current study, what are some of the roles visuals can play in such strategies?

Role of Visuals in Instructional Strategies

Three principal roles may be described for visuals. In an earlier report (Gropper, 1963b), a distinction was made between criterion and intermediary visuals. Criterion visuals are those that appear in the criterion situation and are the stimulus contexts to which the student is expected to respond. To bring appropriate responses under their control, they may appear in the learning situation and, in addition to being criterion contexts, they also serve as learning contexts. For example, in order to be able to identify laboratory apparatus, the actual equipment might be used in the learning situation and students given practice in identifying it. Because visuals are integral to the criterion situation, they are used in the learning situation so that the responses acquired there will transfer to the criterion situation. This is one role visuals can play.

In the earlier discussion of visuals, intermediary visuals were described as those that already possess stimulus control over responses to be practiced. They are not integral to the criterion situation and hence do not constitute criterion stimulus contexts. Although not part of the criterion situation, they are used in the learning situation so that transfer of control may pass from them to the stimulus contexts that are part of the criterion situation. For example, pictures to which students can respond with an appropriate identifying label (the pictures thus possess stimulus control) may be used to teach reading. The student comes to make the appropriate response (cued by the picture) to the printed word. Stimulus control is thus transferred from the picture to the word. This is the second role pictures may play. In this role as a cue, which merely produces a response so that another stimulus may gain control of it, visuals play an intermediary, instrumental, or practical role.

In the second role just described, control of a specific response is passed from one stimulus to another, with the two sets of stimuli being topographically different. For example, control over oral reading responses passing from a picture to a printed word. In a third role, also an intermediary role, topography of stimulus and response may differ. As in the study performed here, pictorial responses to pictorial stimuli facilitated subsequent verbal responding to verbal stimuli (test items). Concepts acquired on the basis of the visual presentation generalized across modes, so that students could respond to verbal contexts (verbal test items), even though no verbal responding was required. Despite the absence of such a requirement, it may be inferred that correct, verbal mediating responses were occurring. It is precisely because verbal responses are in fact under the control of the visual stimuli and their strength quite high that visual stimuli are used. Because of such high response strength, it is assumed, verbal mediating responses are likely to be made to the visual presentation. It is this form of mediation, it is hypothesized, that can account for the generalization that occurred across modes (from pictorial responses to pictorial stimuli in the learning situation to verbal responses to verbal stimuli in the testing situation). Had some feature or dimension of a visual presentation not had stimulus control over a mediating verbal response, then it is unlikely that generalization would have occurred from visual learning to a criterion performance requiring verbal responding (Klaus, 1965).

What are the considerations involved in the use of such intermediary visuals (and responses to them), which may differ in modality from criterion contexts and criterion responses? Why use them instead of using actual criterion contexts and criterion responses in the learning situation?

The question may be illustrated with a practical illustration. For teaching the discriminations and generalizations that underlie concepts and principles in science, it is possible, as shown by data from two studies, to choose between visual and verbal examples. Fxamples in either mode provide appropriate contexts to which students must respond. Having seen a number of prior demonstrations illustrating the apparent loss of weight that occurs when objects are weighed in air and then in water, a student is then presented with a new visual context. He is shown still another object weighed in air and instructed to predict whether the reading on the scale will increase, decrease, or remain the same. The same context might be presented in words and, following a series of prior verbally stated examples, the student would be instructed to predict what would happen to still another verbally described example. Based on such response practice with either visual or verbal contexts, students in this study came to acquire the concepts and principles in Archimedes'

Law. What are the rational considerations on which a choice might be made between presentations of visual rather than verbal examples? What strategy considerations are involved?

Manipulating response difficulty. - There is evidence from both studies described in this volume to suggest that science concepts are more easily acquired from visual rather than verbal examples. This was particularly true when the visual mode was used for both stimulus materials and response options. The ease that the visual mode affords in both cases, it was suggested, derives from well established associations. High strength responses are already under the control of visual stimuli and can readily facilitate concept acquisition. Whatever the interpretation, the data revealing both individual differences in learning from visual and verbal materials and the transfer-facilitating effects of visual presentations suggest that concept acquisition can be made easier through the use of visual (pictorial) presentations. To what practical uses might such a finding be put? Three possibilities suggest themselves: (a) accommodation of individual differences; (b) reduction of the difficulty level of complex subject matter; and (c) setting difficulty levels appropriate to stages of learning.

(a) accommodating individual differences. - Recently completed research by Gagné and Gropper (1965) failed to reveal any significant relationship between special aptitudes, particularly visual aptitudes, and a person's capacity to profit from visual presentations. The results of the present study do not suggest the possession of any special aptitude as calling for visual presentations. On the contrary, it would seem that it is the absence of aptitude, particularly verbal aptitude, which is the biggest component in such IQ measures as Otis IQ, that does appear to call for the use of visual presentations. The evidence suggests that below average students were better able to acquire the concepts taught in both studies by means of pictorial presentations and pictorial responses than by means of counterpart verbal material. Far from possessing any special visual aptitudes, below average students can respond to visual examples because, it is suggested, they, along with their brighter counterparts, have had considerable prior experience in responding to the concrete attributes of many physical objects and events. Such examples are therefore capable, with high probability, of eliciting appropriate responses. Doing well with visuals, far from being a special aptitude, constitutes, so to speak, an easy task.

The two studies reported here were based on the performance of eighth graders. It is reasonable to suppose that the advantages that visuals have for below average eighth graders, might also accrue to students throughout the ability distribution at still lower grade levels. Based on the assumption that at lower age levels the capacity for abstract (verbal) thought is even more diminished, visual presentations using concrete stimuli might be more readily recommended for them.

(b) reducing the difficulty level of complex material. - An instructional strategy might specify a wholly visual (or at least partly visual) presentation for below average students or for very young students as a way of facilitating learning. For complex materials, learning might be facilitated for all, regardless of ability or of age, through the use of a similar strategy. The use of the number line to teach the addition and subtraction of positive and negative numbers comes to mind as an example of such an approach. To the extent that visual techniques can be imagined, formulated, and implemented for such purposes, they might be recommended as a means of reducing the difficulty level of what would otherwise be complex and not easily acquired concepts or principles.

(c) setting difficulty levels to match stages of learning. - It is fairly axiomatic in programmed instruction that learning progresses from what is known to what is unknown, from what is easy to what is difficult. Various strategies are possible for this purpose. The difficulty level of vocabulary can be manipulated. Familiar verbal examples can be used to explicate what is new and abstract. To facilitate ease of response the mode chosen for response practice can be varied. In the REP style of programming, for example, Gropper (1965) requires production responses only after editing responses and these in turn only after recognition responses. As in the case of these various strategies, the use of visuals in early stages of learning can similarly serve to make responses less difficult.

In the present study, the findings of two experiments have shown the advantages of visual presentations that precede rather than follow a more abstract verbal presentation. Being easier, the visual presentation appropriately comes first to match the stage of response readiness of the learner.

For any of the three purposes just described, one of the conditions of the learning experience that can be manipulated through the use of visuals is response difficulty. One of the consequences of such manipulation is the possibility of controlling the frequency of student errors. Error control is a concern because of its assumed relation to achievement. Recent results reported by Kress and Gropper (1964), support such an assumption. Based on two programs and two groups, four correlations were obtained between the number of errors committed and achievement scores. On one program, the correlations for the two groups was -.64 and -.65 and on the second program -.67 and -.70. Despite the fact that the variability of the error distributions were sharply curtailed, sizeable negative correlations were obtained indicating that the more errors students made on programs, the lower their achievement scores were. If, then, there is justifiable concern about error control, the relative ease of visual materials suggests the visual modes as another possible instrument for achieving it.

By proposing pictorial contexts and pictorial responses, the educator can formulate a strategy that can render the learning experience easier. Pictures can be used to cater, as it were, to the response readiness of the learner as this is influenced by the complexity of the material, by the student's particular abilities and experience or lack of them, or by the stage of learning he is about to enter.

The pictorial mode is selected for the learning situation not because criterion contexts are similarly pictorial, but because the conditions of learning can be altered. Intermediary visuals, rather than criterion visuals are used, because they make learning easier (Gropper, 1963b). Pictures are thus used in an instrumental sense.

Facilitating transfer. - To make transfer more likely, it is sometimes appropriate to build criterion contexts into the learning experience. Thus when visuals are both intermediary and criterion at the same time, transfer might be expected to be optimally facilitated. When the criterion situation contains visual contexts, it is reasonable to expect positive transfer to occur when students practice responses to identical or similar contexts in the learning situation. What of those criterion situations however, that do not contain visual contexts? Suppose a criterion test, for example, consists solely of verbal test items. What occurs when the learning situation consists of pictorial responses to pictorial contexts? On the basis of the data reported in Study No. 1, it appears that departure from similarity between learning situation and criterion situation is not nearly so crucial when programmed visuals are used to teach concepts in science.

The findings of the present study seem to indicate that when the learning experience is verbal, students do well on only the verbal test. When the learning experience is visual, students do well on both visual and verbal tests. Transfer across modes appears to occur more readily from visual to verbal than in the reverse direction. In addition, data concerning transfer that occurs from one learning situation to another learning situation also suggest the superiority of the visual/verbal direction.

It may well be that in addition to altering response difficulty, a visual/verbal order of presentation capitalizes on the well established set of associating words with visual experience. Thus it is highly likely that visual presentations produce mediating verbal responses. On the other hand, the opportunity or need to visualize our words do not seem to be as insistent in our everyday experience. Consequently the verbal/visual order of learning or transfer from verbal learning to visual testing is not likely to benefit from mediating visual responses. The greater likelihood of verbal mediation (than visual mediation) may in part account for the superiority of the visual/verbal order of presentation and, when learning is based on visual experience, for the lesser need for similarity between learning and criterion situations.

The visual/verbal order of presentation appears to be superior to the reverse order for two reasons:

(1) Pictorial responding to pictorial material is likely to be easier (for concept learning) than is verbal responding to verbal material. Since early stages of learning are deliberately made easy, visual experience should precede verbal experience.

(2) Transfer appears to be facilitated more readily from visual experience to verbal experience than in the reverse order. Thus, visual experience should precede verbal experience.

Other Strategy Considerations Suggesting Further Research

Visuals may play still other roles in instructional strategies. Suggestions about such roles will merely be offered here, either because the data relating to them from this study are fragmentary or because the present study did not investigate them at all. They are to be considered as issues meriting further study.

(a) providing a variety of learning contexts. - Concepts and principles are more easily acquired and, perhaps better applied, when a broad range of examples is employed to teach them. One way to vary the breadth of learning contexts is to present examples in more than one stimulus mode. Data from Study No. 1 demonstrated that a visual presentation and a verbal presentation (in that order) excelled not only the reverse order of presentation but also two presentations of either the verbal lesson or the visual lesson. Thus a mixed visual and verbal treatment proved superior to a wholly visual and to a wholly verbal one. However, since these latter two treatment conditions merely involved the repetition of the same examples in the second presentation of the lesson, the conclusion to be drawn about breadth of contexts is not so clear-cut. The comparison that needs to be made is, therefore, between a visual/verbal presentation and solely verbal or solely visual presentation that have comparable variety of examples. Should the visual/verbal presentation still prove superior, then this effect would not entirely be attributed to the manipulation of response difficulty (as discussed above). Variations in mode of stimulus presentation might then be considered to be a facilitating factor in the acquisition of a generalized response, i.e., a concept or principle. Generalization across visual and verbal examples is not likely to occur, however, unless the relevant visual stimulus dimensions have verbal responses under their control and unless these responses are at high strength. These are hypotheses for future testing.

(b) facilitating learning tasks. - It was just suggested that a mixture of visual and verbal examples might facilitate the generalization of responses to new situations. It is also suggested that it might be worth exploring the possibility that visual examples alone rather than intermingled with verbal examples might facilitate the acquisition of the discriminations and generalizations on which concepts depend. One possibility is that it might require fewer visual examples for a generalization to be built than would be the case if verbal examples were used. Should these visual examples require less time to present, there would be a decided advantage in using them. However, watching science demonstrations sometimes require more time than reading a verbal, printed statement of an example. Advantages would have to be sought elsewhere -- for example in better retention of the concepts they illustrate.

As to discriminations, might there be advantages to using visual stimulus materials rather than verbal materials? Might they, too, not be acquired on the basis of fewer examples if the examples are visual? Might not the possibility of simultaneous contrasting of examples (particularly with static visuals) rather than contrasting successive examples (usually the case with verbal examples) prove more effective and efficient?

The use of fewer examples on which the acquisition of generalizations and discriminations depend suggests rather paradoxically that, even though it may be easier to respond to visual examples than to verbal examples, step size may be increased. If students are brought to criterion level performance on the basis of fewer examples, each step along the way would obviously be larger.

(c) facilitating transfer. - The results presented here (successful performance on verbal test items even when learning was based on pictorial experience) indicated that transfer across modes occurred. It was hypothesized that this transfer was mediated by verbal responses. It was further hypothesized that, had not such verbal responses been under the control of the pictorial stimuli, transfer would not have occurred. Research in which strength of verbal responses to pictorial stimuli is manipulated can be designed to disclose whether concept acquisition (measured verbally) based on pictorial presentation depends on verbal mediation.

The inferior transfer from verbal learning to visual testing was further interpreted in terms of the lack of high strength visual responses available to mediate such transfer. Comparable research could be designed in which pictorial response strength is also systematically manipulated. Further meriting study are the techniques whereby pictorial responses to verbal stimuli might be brought to higher response strength. At such high strength, they might be capable of playing the mediating role they are often assumed to play.

The issues outlined above, those for which this study has provided answers and those requiring further research, it can be readily seen stem from behavioral considerations, from an analytic view of the learning processes and the variables of which they are a function. Many other issues could be suggested, but the ones described here, are restricted to those stemming from the research just completed.

SUMMARY

The integration of words and pictures in the two studies reported in this volume was accomplished quite unconventionally. In one study, an entire topic, "Archimedes' Law," was covered in a self-contained, entirely pictorial lesson and also in a self-contained, entirely verbal lesson. Students acquired all the concepts and principles making up Archimedes' Law first on the basis of one lesson and then once again on the basis of the second. In a second study involving a lesson on "pressure," only one or two concepts or principles were covered in each visual segment and then again in each verbal segment. It required all five visual segments in the lesson to teach all the concepts and principles. Similarly it took all five verbal segments to teach all the concepts and principles. Thus, the only difference between the two studies was that the lesson in the second study was segmented. What was common to both studies was the provision for the acquisition of the discriminations and generalizations underlying the concepts and principles to be taught solely on the basis of programmed visual material, solely on the basis of the programmed verbal material, and then on the basis of both sets of materials combined.

In the visual/verbal order of presentation, a student acquired the discriminations and generalizations (necessary to understand the concepts being taught) on the basis of the pictorial materials first; he then acquired them once more, in more technical language, on the basis of verbal materials. For example, on the basis of the solely visual lesson on Archimedes' Law he learned the principle that objects weigh less in water than in air. The subsequent verbal lesson taught him that there "is an apparent loss of weight" when objects are weighed in water.

This procedure whereby programmed visual lessons on their own are used to teach concepts is quite different from the conventional use of pictorial material. Typically a visual example is used to precede or to follow a verbal statement or principle or a verbally described example. Rarely are a sufficient number of visual examples used and rarely is the opportunity afforded to practice the necessary discriminations about the examples so that the relevant concept is fully acquired on the basis of the visual examples alone. Concepts cannot in conventional uses of pictures be acquired either on the basis of the visual example(s) alone or on the basis of the verbal example(s) alone. In contrast, in the procedure used in these studies, concepts were fully acquired on the basis of either the visual or the verbal series of examples. Thus, when the recommendation is made that visuals should precede the verbal treatment, it does not mean that a single visual followed by verbal statements of principles will suffice. The concepts must be first acquired on the basis of the visual treatment (using as many examples as is needed) and only then should the same concepts be covered in the verbal treatment. The purpose of including the verbal lesson is to teach the student the technical language describing the concepts he already understands.

An efficient integration of words and pictures would appear to call for the following prescription: the use of a single concept film (using visuals) followed by verbal materials (whether in print, in lecture, or in film or televised form). Pictures and words would be serially intermixed as called for by a particular instructional strategy. Visual presentations would be designed to facilitate acquisition of the discriminations and generalizations on which understanding of concepts and principles depended. Further, pictorial responses to such presentations would be required. One role that visuals of the sort just described can play in an instructional strategy is to make concept learning easier. This strategy would be followed: (a) for students of lower verbal ability or for young students; (b) for all students when concepts to be learned are complex; and (c) for matching difficulty requirements at various stages of learning. Also, since it appears desirable that visual and verbal experience be integrated, a second role visuals can play (when they come first) is to facilitate transfer to a verbal learning experience.

These considerations stem from a behavioral way of looking at learning from pictures. Further research can provide evidence as to the adequacy of learning theory to account for such learning. Only as such evidence accumulates and learning theory becomes increasingly comprehensive can applied problems be readily solved. The quickest route to their solution, it is suggested, is through the rigorous testing of a theory, rather than the eclectic, ad hoc borrowing from more than one theory to account for particular phenomena.

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APPENDICES

Study No. 1 - Archimedes' Law

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APPENDIX A

VERBAL LESSON ON ARCHIMEDES' LAW*

Practice Frame 1.

There is less heat in cold water than there is in HOT water.

Practice Frame 2.

The amount of heat there is in hot water depends on how HOT the WATER is.

1.

Heavy objects cause large readings on a scale.
Light objects cause small READINGS on a scale.

2.

We can find out how much an object weighs from the READING on a scale.

3.

An object's weight is indicated by the READING on a SCALE.

4.

An object pulled down by a 5 lb. force has a 5 lb. scale READING.

5.

The smaller the force pulling an object down the SMALLER the SCALE READING.

6.

The bigger the force pulling an object down, the BIGGER THE SCALE READING.

7.

The size of the force pulling an object down determines how BIG the SCALE RZADING is.

8.

To reduce means to make something smaller. We can REDUCE a scale reading and make it SMALLER.

9.

A scale reading can be REDUCED from 9 lbs. to 5 lbs.

10.

By pushing up we REDUCE a scale reading from 7 lbs. to 3 lbs., making it LESS than before.

11.

When a scale reading is REDUCED from 10 lbs. to 2 lbs., it is 8 lbs. less than before.

12.

Pushing up reduces a scale reading from 9 lbs. to 3 lbs.
Now it is 6 lbs. LESS than before.

13.

Pushing an object up reduces a scale reading and it is then LESS than BEFORE.

14.

Pushing an object up REDUCES a scale reading. It is then LESS than BEFORE.

---

*Subjects made constructed responses for each of the following frames. The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. The correct constructed responses appear in capital letters.

15.

After an upward push, a scale reading of 50 lbs. will be LESS than 50 lbs.

16.

Pushing up with a force of 5 lbs. REDUCES a scale reading from 9 lbs. to 4 lbs.

17.

Pushing up with a 9 lb. force reduces the scale READING from 13 lbs. to 4 LBS.

18.

Pushing up with a 25 lb. force reduces the SCALE READING from 75 lbs. to 50 LBS.

19.

Objects in water float because they are PUSHED up by the water.

20.

The upward push by water is called a buoyant force.
Water pushes objects up with a BUOYANT FORCE.

21.

A man floating in water is pushed up by the BUOYANT FORCE of the water.

22.

When an object is put under water, we say it is submerged.
Objects under water are SUBMERGED.

23.

An object is pushed up by the water even when it is SUBMERGED under water.

24.

Submerged objects are PUSHED up by the BUOYANT force of the water.

25.

In water, scale readings are reduced since objects are PUSHED up by the BUOYANT FORCE of water.

26.

Scale readings are less in water since objects are PUSHED up by the BUOYANT FORCE of WATER.

27.

Scale readings are less in water since objects are PUSHED UP BY THE BUOYANT FORCE OF WATER.

28.

In water a scale reading will be LESS than in air since objects are PUSHED UP BY A BUOYANT FORCE.

29.

A reading is reduced from 9 lbs. to 4 lbs. when a 5 lb. buoyant force PUSHES the object up.

30.

A reading is reduced from 8 lbs. to 2 lbs. when a 6 lb. BUOYANT force pushes the object up.

31.

A reading is reduced from 4 lbs. to 1 lb. when a 3 lb. BUOYANT FORCE pushes the OBJECT up.

32.

A reading is reduced from 9 lbs. to 1 lb. when an 8 lb. BUCYANT FORCE PUSHES THE OBJECT UP.

33.

When a scale reading is reduced by 8 lbs., it will go from 10 lbs. to 2 lbs.

34.

Water pushes an object up with a buoyant force of 4 lbs.
The scale reading will be REDUCED by 4 lbs.

35.

Water pushes an object up with a buoyant force of 7 lbs.
The scale READING will be reduced by 7 LBS.

36.

A scale reading that changes from 12 lbs. to 3 lbs. is REDUCED by 9 lbs.

37.

A 35 lb. force pushing up reduces the scale reading by 35 lbs. making it 35 lbs. LESS than before.

38.

A scale reading reduced by 4 lbs. is 4 lbs. LESS than before.
A reading changes from 9 lbs. to 5 LBS.

39.

A scale reading reduced by 40 lbs. changes MORE than a scale reading reduced by only 10 lbs.

40.

Scale readings are reduced by 25 lb. and 40 lb. forces.
A reading is changed more by the 40 lb. FORCE.

41.

An 8 lb. force reduces a reading from 9 lbs. to 1 lb.
A 2 lb. force only reduces it from 9 lbs. to 7 lbs.

42.

The bigger the force pushing an object up, the MORE the scale reading is changed.

43.

The smaller the force pushing an object up, the LESS the scale reading is changed.

44.

A 50 lb. force reduces a reading by 50 lbs.
A 10 lb. force REDUCES a reading by only 10 lbs.

45.

The amount of force pushing up determines how MUCH the scale reading is REDUCED.

46.

The amount of force pushing up determines HOW MUCH THE SCALE READING IS REDUCED.

47.

A scale reading that is reduced by 10 lbs. changes LESS than a scale reading reduced by 50 lbs.

48.

Objects are pushed up by the buoyant force of water, reducing the SCALE READING.

49.

The buoyant force of water pushes objects up causing the SCALE READING to be REDUCED.

50.

The buoyant force equals 30 lbs.
A reading will be reduced from 35 lbs. in air to 5 lbs. in water.

51.

A scale reads 35 lbs. in air.
If the buoyant force equals 10 lbs., the scale will read 25 LBS. in water.

52.

Objects cause water to overflow.
A rock put in water will cause the water to OVERFLOW.

53.

An object submerged in a full container of water will make the water OVERFLOW.

54.

A stone put in a full glass of water will make the WATER OVERFLOW.

55.

The overflow is collected in a beaker.
By putting the beaker on a scale we can WEIGH the overflow.

56.

The larger the amount of overflow we put on the scale, the MORE it will WEIGH.

57.

The smaller the amount of overflow we put on the scale, the LESS it will WEIGH.

58.

If the overflow weighs 25 lbs., the submerged object is PUSHED up with a buoyant force of 25 lbs.

59.

If the overflow weighs 34 lbs., the submerged object is PUSHED up with a BUOYANT FORCE of 34 lbs.

60.

If the overflow weighs 19 lbs., the submerged object is PUSHED UP with a BUOYANT FORCE of 19 LBS.

61.

A 10 lb. overflow results in a 10 lb. buoyant force.
A 2 lb. overflow results in only a 2 lb. buoyant force.

62.

The amount of buoyant force pushing up depends on how much the overflow WEIGHS.

63.

How big the buoyant force is depends on the WEIGHT of the water that OVERFLOWS.

64.

The more the overflow weighs, the bigger the BUOYANT FORCE pushing up.

65.

The less the overflow weighs, the SMALLER the BUOYANT FORCE pushing up.

66.

A 9 lb. overflow results in a 9 lb. BUOYANT FORCE pushing an object up.

67.

A 5 lb. overflow produces a 5 lb. BUOYANT FORCE pushing up which reduces a scale READING by 5 LBS.

68.

A 9 lb. overflow produces a 9 lb. buoyant force pushing up which REDUCES a scale reading by 9 LBS.

69.

A 3 lb. overflow produces a 3 lb. BUOYANT force pushing up which REDUCES a scale reading by 3 lbs.

70.

A 7 lb. overflow produces a 7 LB. buoyant force which REDUCES the SCALE READING by 7 LBS.

71.

A 6 lb. buoyant force REDUCES the scale reading by 6 lbs.
The reading changes from 9 lbs. to 3 lbs.

72.

8 lbs. of water overflows.
The buoyant force equals 8 lbs.
The reading is REDUCED from 10 to 2 lbs.

73.

The overflow weighs 6 lbs.
The BUOYANT FORCE equals 6 LBS. reducing the reading from 9 lbs. to 3 LBS.

74.

The amount of water that overflows depends on the size of the submerged OBJECT.

75.

More water overflows from submerging a large object than from a SMALL object.

76.

The bigger the submerged object the MORE water will OVERFLOW.

77.

How much water overflows depends on the SIZE of the submerged OBJECT.

78.

The smaller the submerged object the LESS water will OVERFLOW.

79.

If we put the overflow on a scale, the more water that overflows the more the overflow will WEIGH.

80.

The bigger the object the MORE water will overflow and the MORE the overflow will WEIGH.

81.

The smaller the object the less water will OVERFLOW and the LESS the overflow will WEIGH.

82.

The more the overflow weighs, the BIGGER the BUOYANT FORCE pushing up.

83.

The less the overflow weighs, the SMALLER the BUOYANT FORCE pushing up.

84.

The bigger an object, the MORE the overflow will weigh and the BIGGER the buoyant force pushing up.

85.

The smaller an object the LESS the overflow will weigh and the SMALLER the BUOYANT FORCE pushing up.

86.

The smaller the buoyant force pushing objects up the LESS the scale reading will change.

87.

The bigger the buoyant force, the MORE the scale reading will change.

88.

Copy the following words:
Reduce ________________
Reduction ________________

89.

The overflow, buoyant force, and reduction in scale reading depend on the SIZE of the object.

90.

The overflow, buoyant force, and reduction in scale reading depend on the SIZE of the OBJECT.

91.

The bigger the object put in water, the MORE water will OVERFLOW.

92.

The more the overflow the BIGGER the buoyant force and the MORE the scale reading is changed.

93.

The less the overflow the LESS the buoyant force and the LESS the scale reading is changed.

94.

Compare a 14 lb. and a 6 lb. overflow. A smaller buoyant force will result from the 6 lb. overflow.

95.

An object is submerged in water and 15 lbs. of water overflows. The BUOYANT FORCE also equals 15 lbs.

96.

The amount of buoyant force pushing up depends on the weight of the water that OVERFLOWS.

97.

The amount of buoyant force pushing up depends on the WEIGHT of the water that OVERFLOWS.

98.

The amount of buoyant force pushing up depends on the WEIGHT of the WATER that OVERFLOWS.

99.

The buoyant force of water pushes submerged objects up causing scale readings to be REDUCED.

100.

If the buoyant force equals 15 lbs., the reading on the scale will be REDUCED by 15 LBS.

101.

How much the scale reading is reduced depends on the SIZE of the BUOYANT FORCE.

102.

A 9 lb. overflow results in a 9 lb. BUOYANT FORCE that REDUCES the scale reading from 12 lbs. to 3 lbs.

103.

If the overflow weighs 30 lbs., the scale reading will be REDUCED from 40 lbs. to 10 lbs.

104.

If the overflow weighs 20 lbs., the scale reading will be REDUCED from 60 lbs. to 40 LBS.

105.

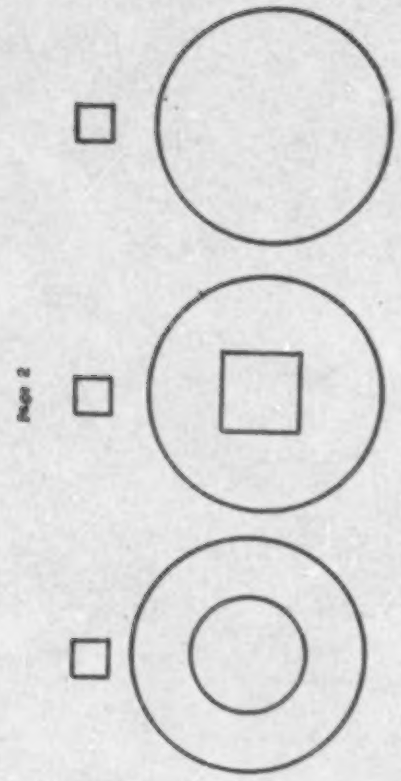
The size of the buoyant force pushing up depends on the WEIGHT of the water that OVERFLOWS.

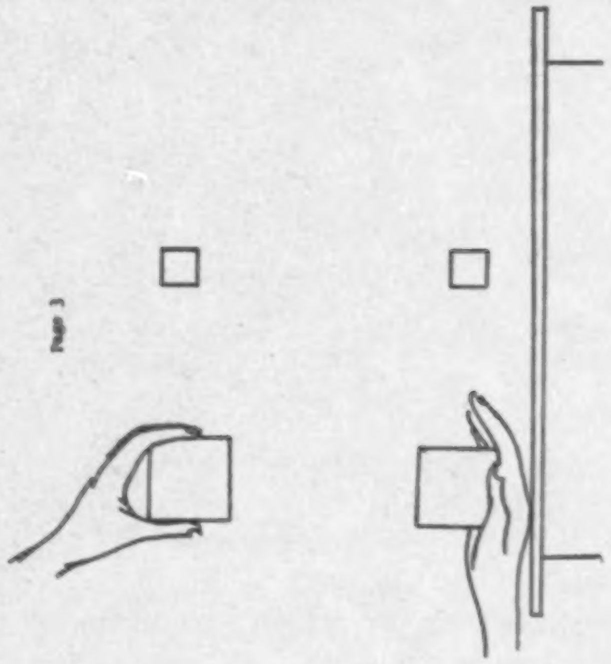
106.

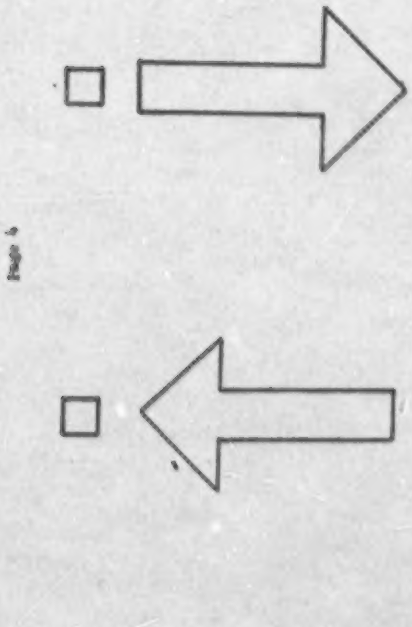
The size of the buoyant force pushing up depends on THE WEIGHT OF THE WATER THAT OVERFLOWS.

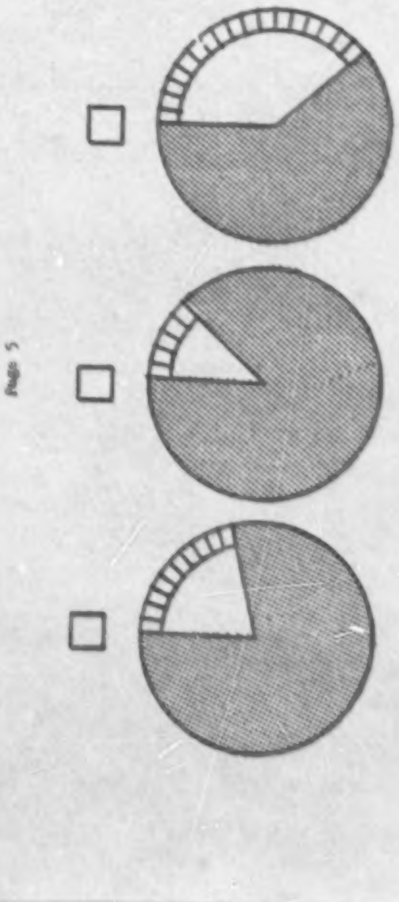
APPENDIX B

WORKBOOK FOR RECORDING VISUAL DISCRIMINATIONS FOR LESSON ON ARCHIMEDES' LAW









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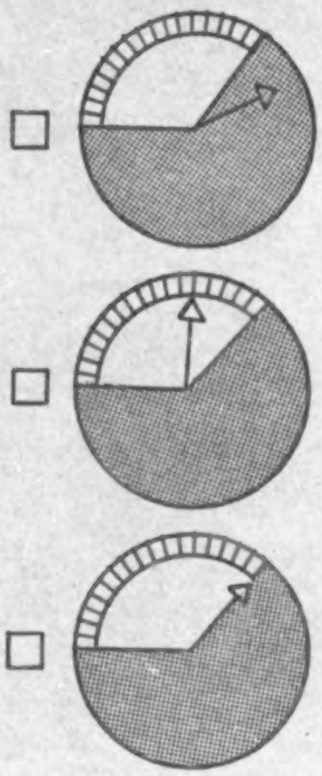

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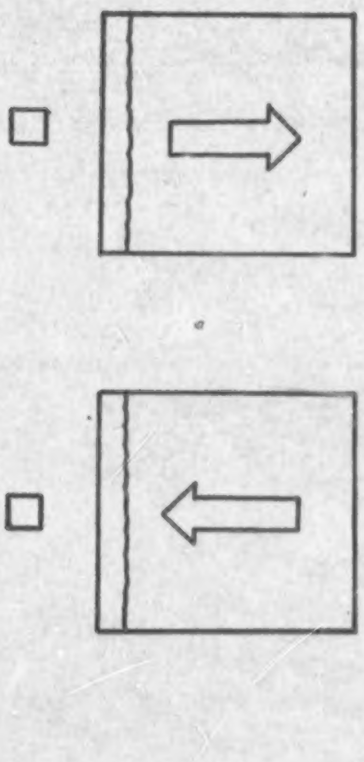

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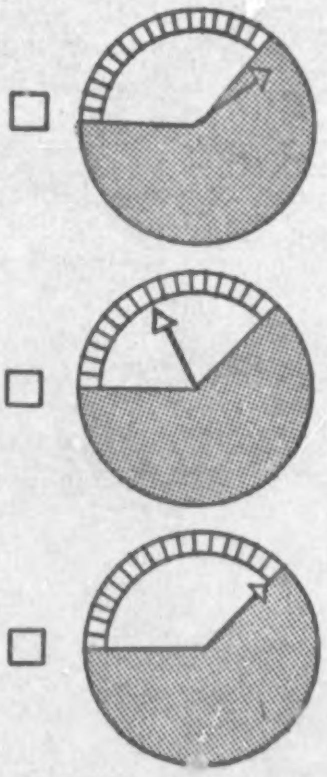

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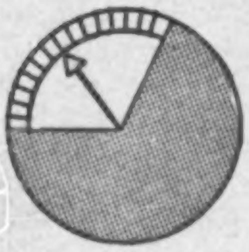

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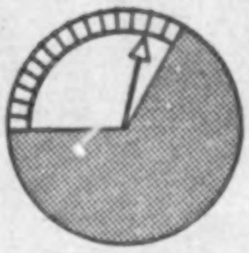

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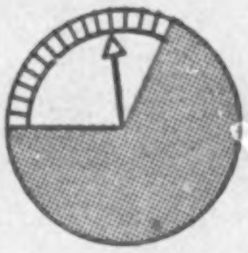

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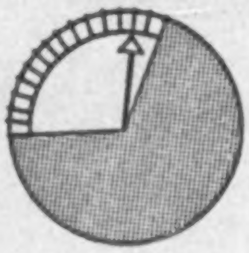

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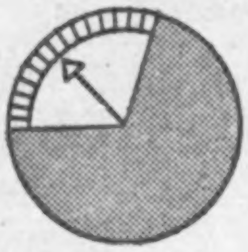

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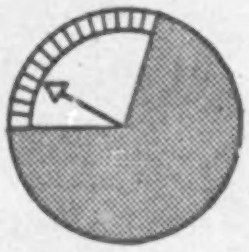

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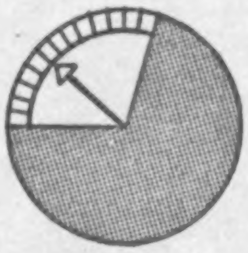

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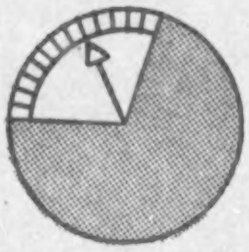

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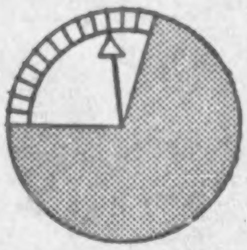

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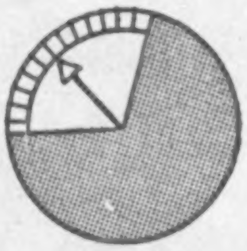

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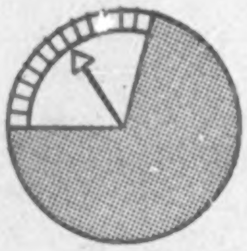

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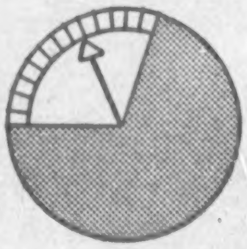

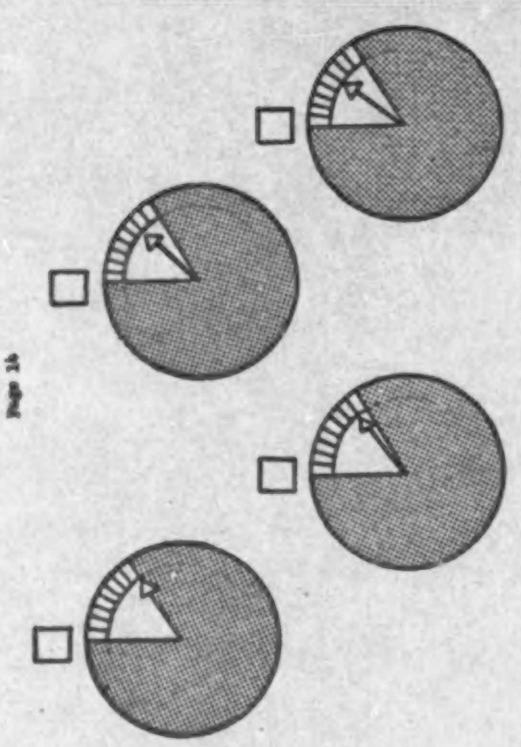
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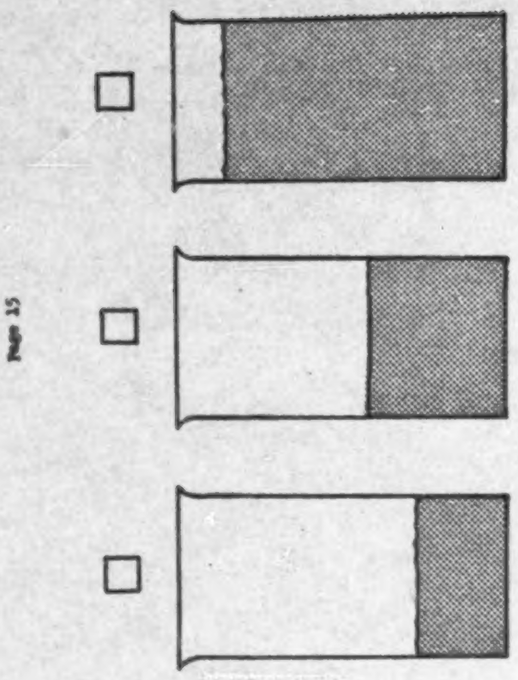
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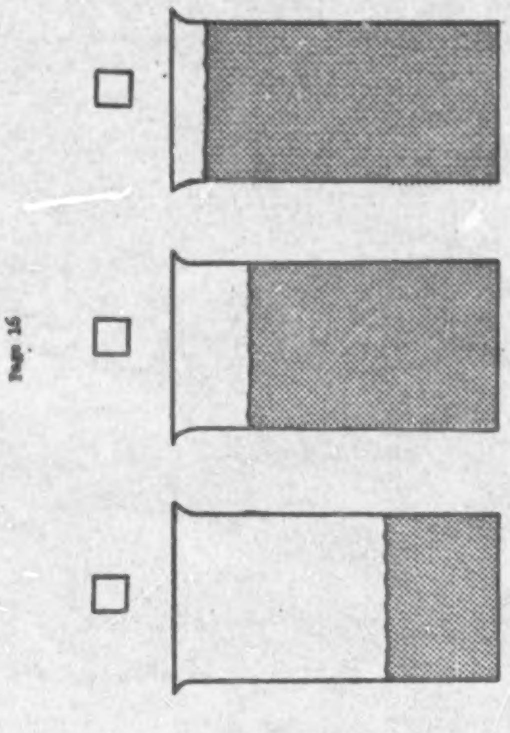
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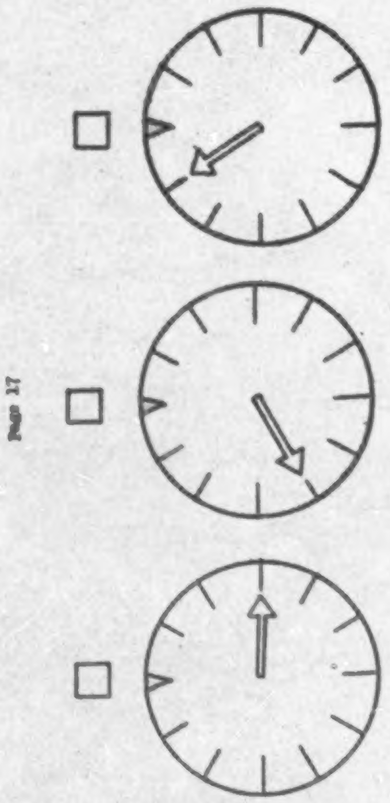
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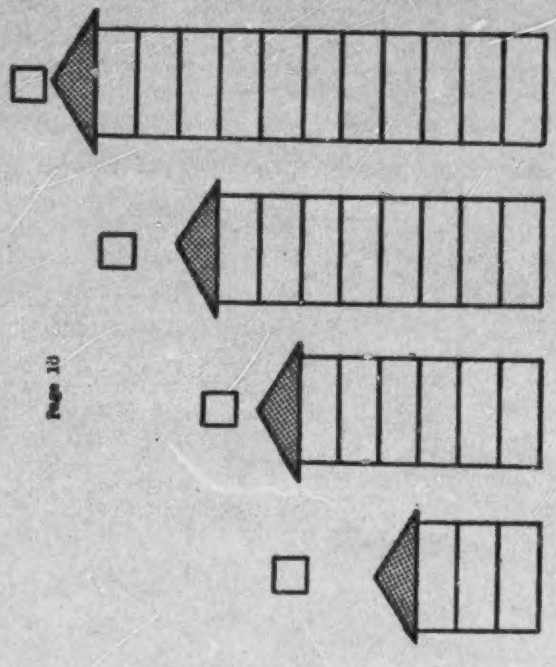

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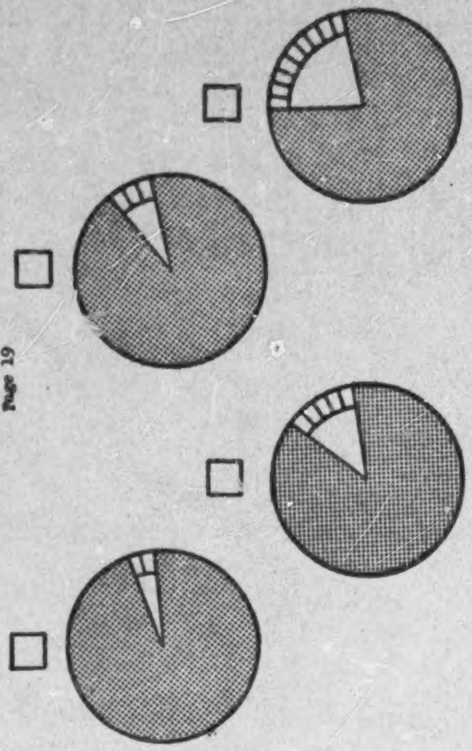

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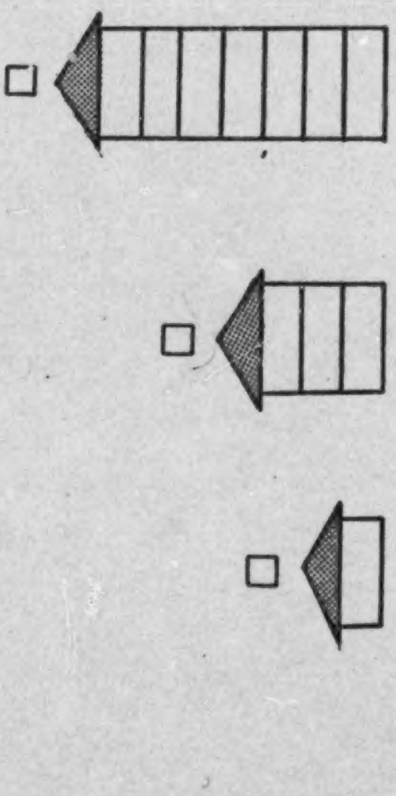

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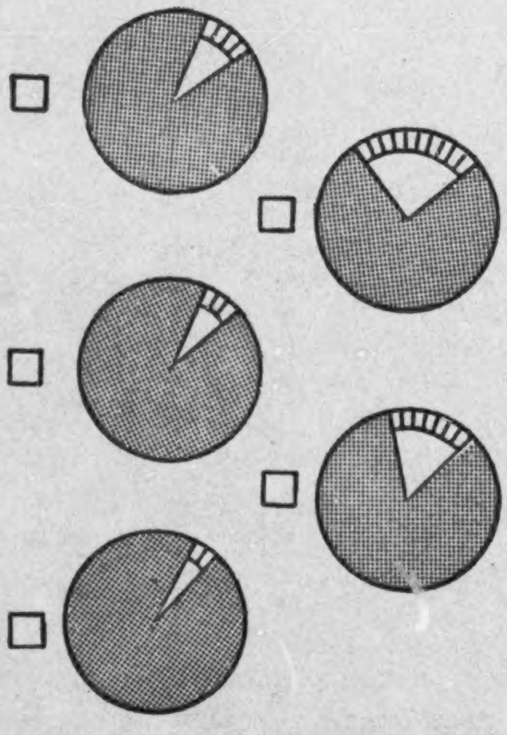

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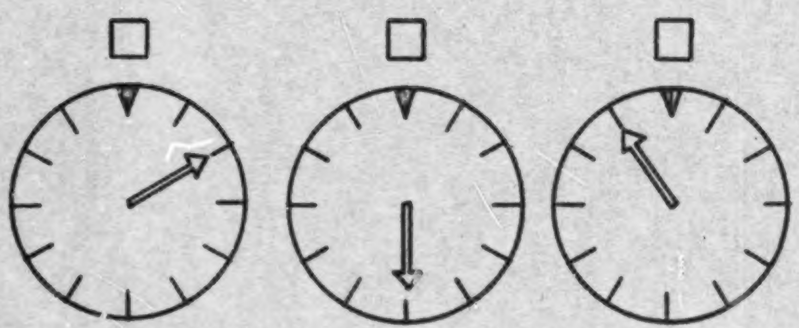

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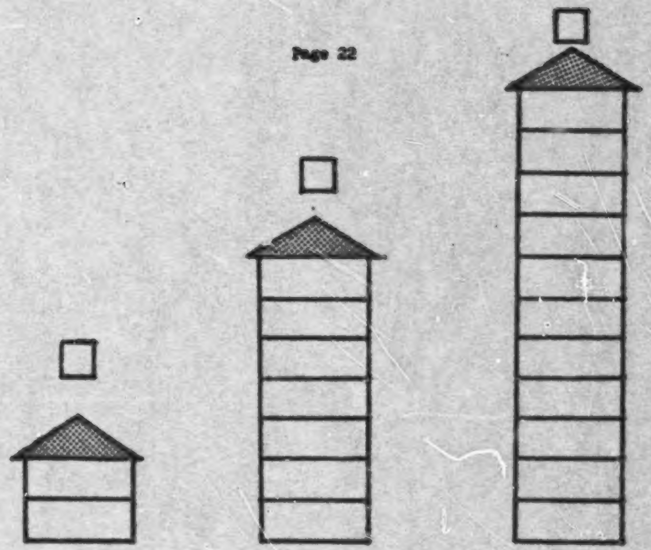

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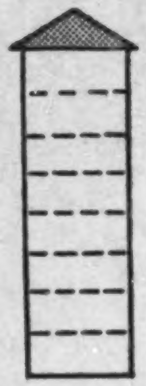

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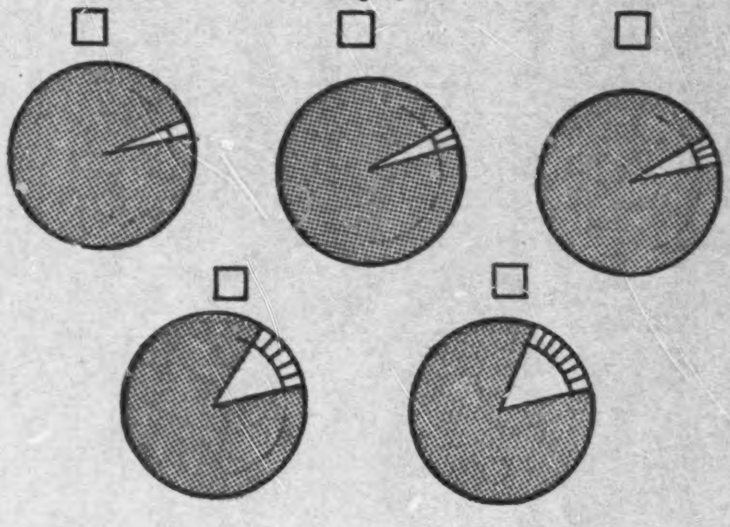

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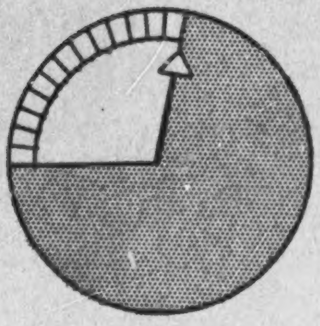

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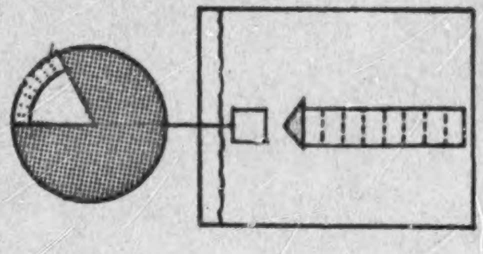

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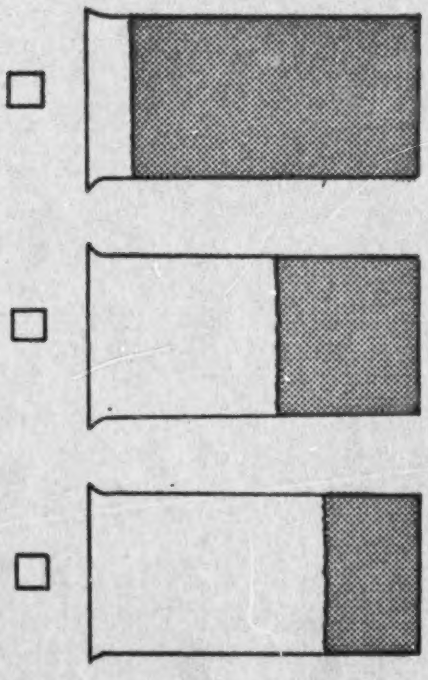

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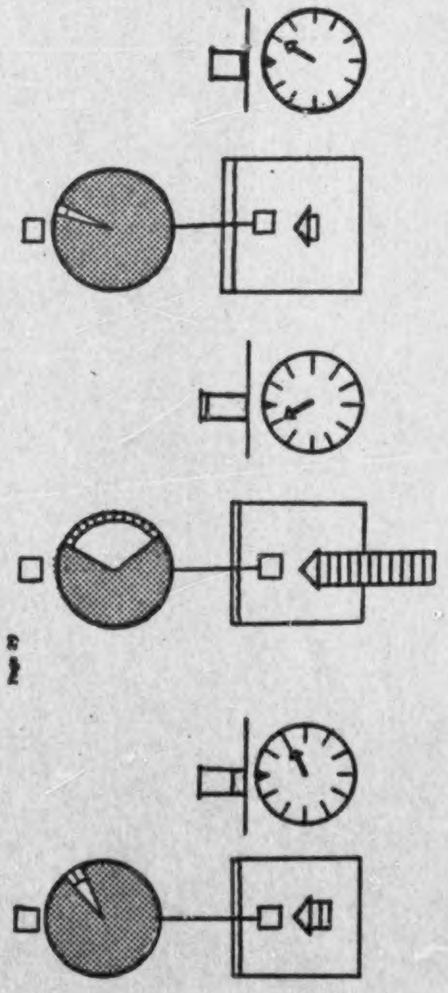

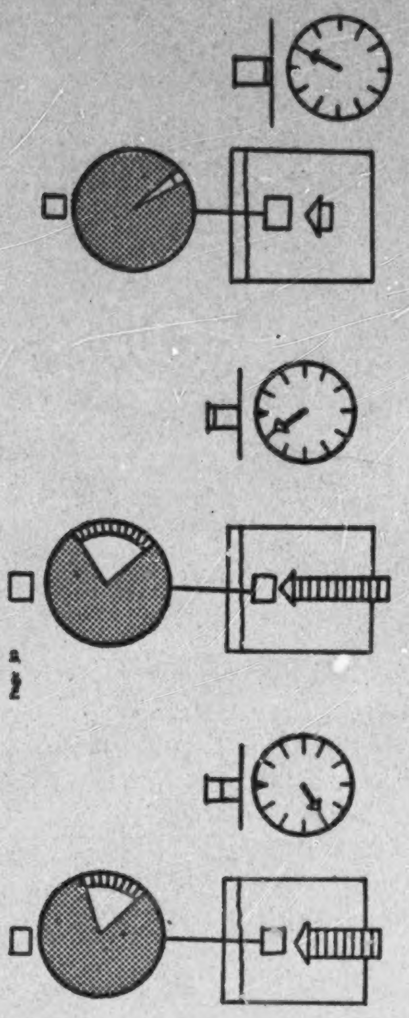

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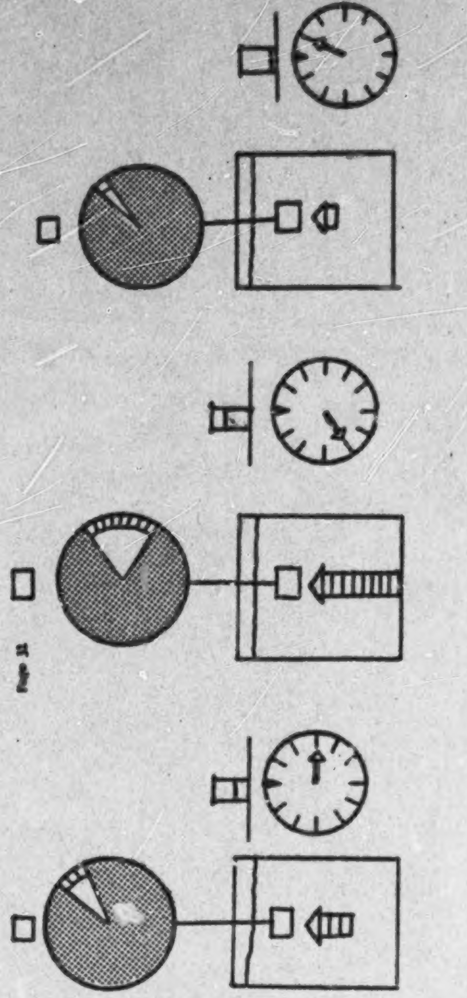

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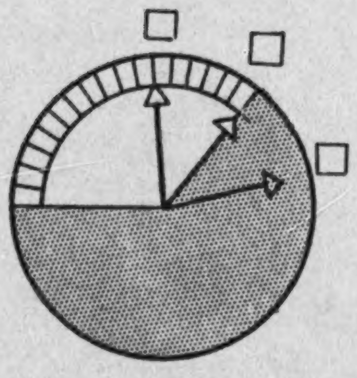

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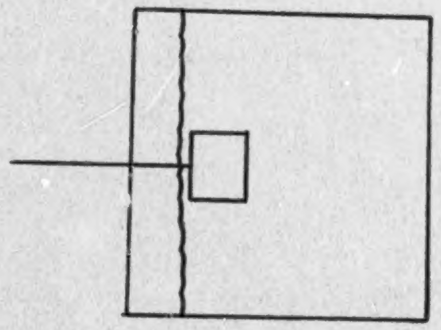

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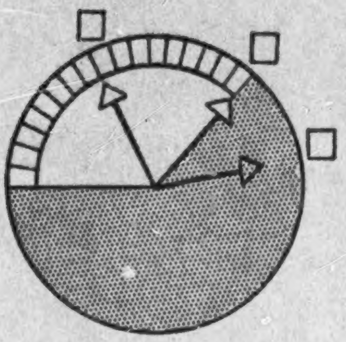

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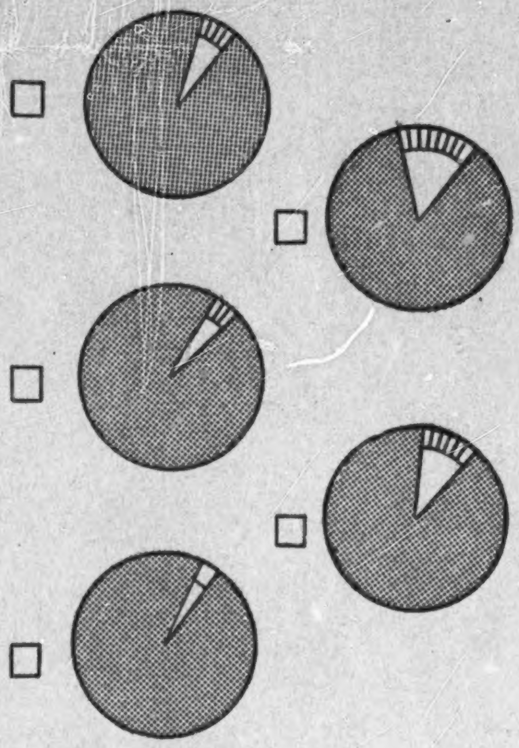

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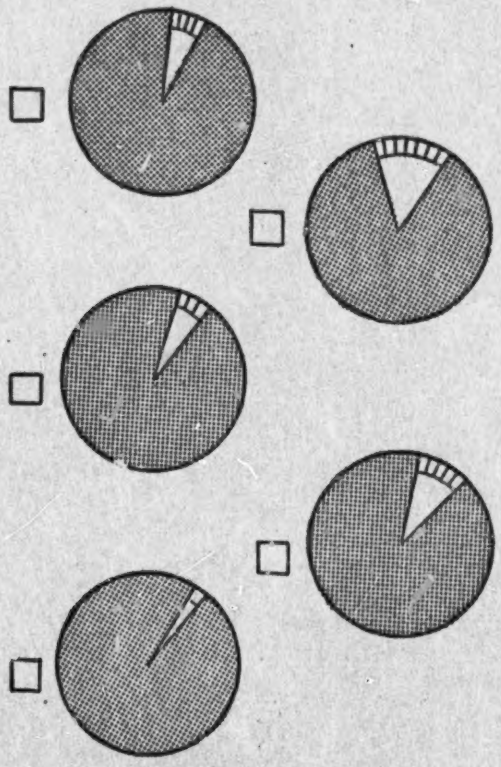

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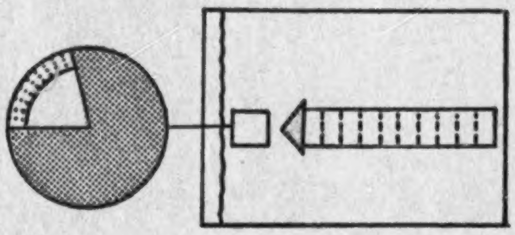

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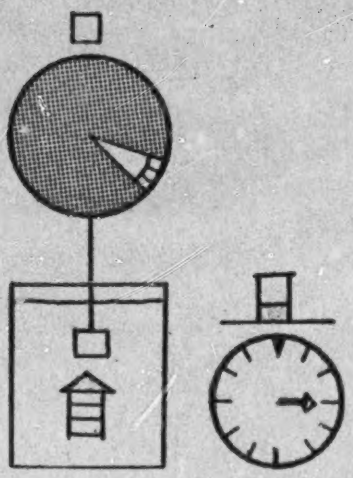
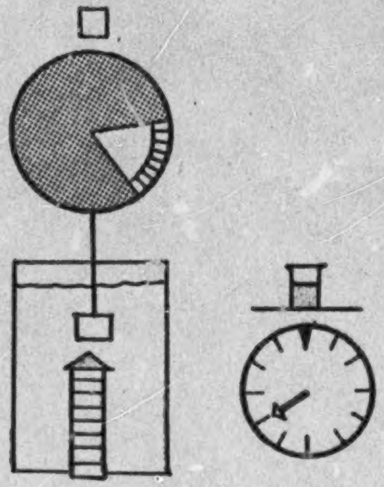
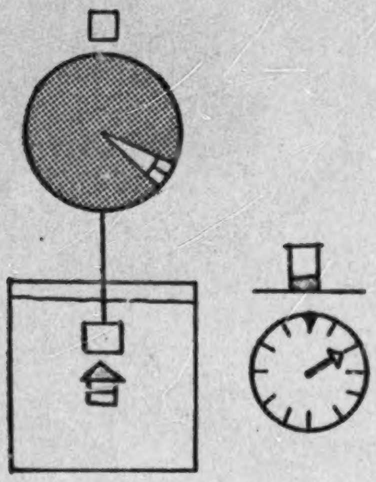






APPENDIX C

CRITERION ACHIEVEMENT TESTS FOR LESSON ON ARCHIMEDES' LAW

I. VERBAL ITEMS

Form A

Part 1

In the space provided, put an X next to the answer you think is best for each of the following questions.

1. It is usually easier to lift a heavy object in water than it is on land because the

   _____ pull of gravity is less in water.
   _____ object has no weight in water.
   _____ water helps you lift the object.
   _____ object exerts an upward push.
   _____ object no longer pushes down.

2. A metal ball attached to a scale is weighed under water. The scale reads 35 lbs. The ball is raised out of water and weighed in air. The most likely reading on the scale will now be

   _____ 0 lbs.
   _____ 25 lbs.
   _____ 30 lbs.
   _____ 35 lbs.
   _____ 40 lbs.

3. The reading on a scale for a square box is 32 lbs. While still on the scale the box is pushed up with a force of 2 lbs. The most likely reading on the scale will be

   _____ 0 lbs.
   _____ 32 lbs.
   _____ 34 lbs.
   _____ 36 lbs.
   _____ none of the above.

4. The scale reads 20 lbs. for a rock weighed in air. While still attached to the scale, the rock is lowered under water. The most likely reading on the scale will now be

   _____ 0 lbs.
   _____ 15 lbs.
   _____ 20 lbs.
   _____ 25 lbs.
   _____ none of the above.

5. If we weighed a man floating on his back in a full swimming pool, the reading on the scale would be zero. When the man got into the pool, the water that he caused to overflow weighed

_____ 0 lbs.
_____ less than the man's weight in air.
_____ the same as the man's weight in air.
_____ more than the man's weight in air.
_____ none of the above.

6. When a stick is lowered into a full pan of water, the water that spills over is collected and weighed. Knowing only the weight of the overflow, we would also know the

_____ increase in the pull of gravity.
_____ decrease in the pull of gravity.
_____ push by the water on the stick.
_____ weight of the stick in air.
_____ weight of the stick in water.

A brick attached to a hanging scale is lowered into a full pan of water. Answer the following two questions about the brick and the scale.

7. If the reading on the scale changes when the brick is lowered into the water, it is because the

_____ pull of gravity has decreased.
_____ pull of gravity has increased.
_____ water pushes the brick up.
_____ water weights the brick down.
_____ brick pushes the water up.

8. The amount of the change that would occur in the reading on the scale when the brick is lowered into the water would depend on

_____ the size of the original reading.
_____ the weight of the overflow.
_____ how much gravity increased.
_____ how much gravity decreased.
_____ the depth of the water.

Part 2 - Form A

In the space provided, put an X next to the answer you think is best for each of the following questions.

1. Object A is weighed on one scale. Object B is weighed on another scale. Then both objects while still attached to the scale are lowered into separate tanks of water. The change on the scale is bigger for object A. We can therefore say that

_____ object A is bigger than B.
_____ the overflow from object A weighs more than the overflow from B.
_____ the water exerts a larger force on A than on B.
_____ all of the above.

2. If an object attached to a scale is lowered into a full container of water, the amount of force exerted on the object by the water depends on the

_____ depth of the water.
_____ size of the container.
_____ size of the pull of gravity.
_____ size of the object.
_____ all of the above.

3. Two objects, A and B, are each lowered into a separate tank of water. Object A causes 7 lbs. of water to overflow. Object B causes 8 lbs. of water to overflow. We can therefore say that

_____ both objects are equal in size.
_____ both objects are pushed up by the water with equal force.
_____ object A is pushed up by the water with less force.
_____ object A is pushed up by the water with more force.
_____ neither object is affected by the water.

4. The upward force exerted by water on objects causes

_____ an increase in the pull of gravity.
_____ a decrease in the pull of gravity.
_____ objects to appear to weigh more.
_____ objects to appear to weigh less.
_____ none of the above.

5. If we apply an upward force with our hand to an object attached to a scale, the size of the change that occurs in the reading on the scale depends on the size of the

_____ object.
_____ original reading.
_____ upward force.
_____ scale.
_____ hand.

6. Objects put under water are pushed up by the water. The upward push by water is equal to the

_____ weight of the object in air.
_____ weight of the object in water.
_____ weight of the overflow.
_____ increase in the pull of gravity.
_____ decrease in the pull of gravity.

7. An object is weighed in a closed container from which all air has been removed. Then it is taken out of the container and weighed in air. The scale reads less in air because the

_____ pull of gravity is less without air.
_____ pull of gravity is less in air.
_____ scales are more accurate in air.
_____ object is pushed down in air.
_____ object is pushed up by air.

8. The reading on a scale changes from 11 lbs. to 7 lbs. when an object is lowered in water. The overflow caused by that object weighs

_____ 0 lbs.
_____ 4 lbs.
_____ 7 lbs.
_____ 11 lbs.
_____ 18 lbs.

9. A small metal ball is lowered into a full cup of water. The force that the water exerts on the ball is equal to the weight of the

_____ water in the cup.
_____ water that overflows.
_____ ball in air.
_____ ball in water.
_____ none of the above.

Part 3 - Form A

Each of several objects, while hanging from a scale, is lowered into a full tank of water. Based on the information about each object in the following table, fill in the blank spaces:

	Scale reading when object is in air	Scale reading when object is in water	Weight of water that overflows
Object #1	25 lbs.	21 lbs.	
Object #2	34 lbs.		10 lbs.
Object #3		10 lbs.	5 lbs.
Object #4	22 lbs.	18 lbs.	
Object #5	50 lbs.		50 lbs.

II. VERBAL ITEMS

Form B

Part 1

In the space provided, put an X next to the answer you think is best for each of the following questions.

1. It is easier to hold a person up in water than it is on land because

_____ people do not weigh anything in water.
_____ gravity does not pull objects down in water.
_____ the water helps to hold the person up.
_____ the person being held pushes up more in water.
_____ the person being held isn't able to push down in water.

2. A solid metal ball attached to a scale is weighed under water. The scale reads 22 lbs. The metal ball is raised out of the water and weighed in air. The most likely reading on the scale will now be

_____ 0 lbs.
_____ 18 lbs.
_____ 20 lbs.
_____ 22 lbs.
_____ 26 lbs.

3. A large box being weighed on a hanging scale is pushed up by a man's hand with a 10 lb. force. While the man is still pushing the box up, the scale reads 32 lbs. If the man stopped pushing the box up, the most likely reading on the scale would be

_____ 0 lbs.
_____ 10 lbs.
_____ 22 lbs.
_____ 32 lbs.
_____ none of the above.

4. The scale reads 30 lbs. for an iron bar weighed in air. The iron bar is lowered into water while still attached to the scale. The scale will now probably read

_____ 0 lbs.
_____ 20 lbs.
_____ 30 lbs.
_____ 40 lbs.
_____ none of the above.

5. If we weighed a log while it was floating in a large tank, the reading on the scale would be zero. When we put the long in the tank, some water would overflow. The overflow weighs

_____ 0 lbs.
_____ less than the log's weight in air.
_____ the same as the log's weight in air.
_____ more than the log's weight in air.
_____ none of the above.

6. When a bowling ball is put into a large pan of water, the water that overflows is collected. Knowing only the weight of the overflow, we would also know the

    _____ weight of the bowling ball in air.
    _____ weight of the bowling ball in water.
    _____ size of the force exerted by the water.
    _____ the depth of the water in the pan.
    _____ how much the pull of gravity changed.

A large rock attached to a hanging scale is lowered into a full pan of water. Answer the following two questions about the rock and the scale.

7. If the same rock is weighed in air and also weighed while under water, two different measurements on the scale result. This is because

    _____ water weights the object down.
    _____ water pushes the object up.
    _____ the pull of gravity increases in water.
    _____ the pull of gravity decreases in water.
    _____ none of the above.

8. When the rock is lowered into the full pan of water, some water overflows. The weight of the overflow determines the size of the

    _____ original scale reading.
    _____ pan of water.
    _____ increase in the pull of gravity.
    _____ decrease in the pull of gravity.
    _____ change in the reading on the scale.

Part 2 - Form B

In the space provided, put an X next to the answer you think is best for each of the following questions.

1. Object A is weighed on one scale. Object B is weighed on another scale. Then both objects while still attached to the scales are lowered into separate tanks of water. The change on the scale is bigger for object A. We can therefore say that

    _____ object A is bigger than B.
    _____ the overflow from object A weighs more than the overflow from B
    _____ the water exerts a larger force on A than on B.
    _____ all of the above.

2. An object attached to a scale is lowered into water. The size of the object determines the

    _____ size of the change in the reading on the scale.
    _____ weight of the overflow.
    _____ size of the force exerted by the water on the object.
    _____ all of the above.

3. Two metal objects are each put into jars of water. Object A makes 3 ounces of water overflow. Object B makes 4 ounces of water overflow. We can therefore say that

_____ neither object is affected by the water.
_____ both objects are equal in size.
_____ both objects are pushed equally by the water.
_____ object A is pushed less than object B by the water.
_____ object A is pushed more than object B by the water.

4. Because water exerts an upward force on objects

_____ the pull of gravity increases.
_____ the pull of gravity decreases.
_____ objects appear to weigh less.
_____ objects appear to weigh more.
_____ none of the above.

5. An object is attached to a hanging scale. If we push the object up with our hand, the change in the scale reading depends on the size of the

_____ object.
_____ original reading.
_____ push.
_____ scale.
_____ hand.

6. Objects put under water are affected by the water. Which of the following statements best describes this effect?

_____ The weight of the object in air determines the upward push by the water.
_____ The weight of the object in water determines the upward push by the water.
_____ The upward push by the water is determined by the weight of the overflow.
_____ The upward push by water is determined by the size of the force of gravity.
_____ None of the above.

7. A scale reads less when a fish is weighed in salt water than when it is weighed in fresh water. This is because

_____ fresh water pushes up more.
_____ salt water pushes up less.
_____ salt water pushes up more.
_____ the pull of gravity does not operate in salt water.
_____ fish swim closer to the surface in salt water.

8. A brick is attached to a weighing scale and the scale reads 20 lbs. When the brick is lowered into a full tank of water, the scale reads 13 lbs. The water overflowing from the tank weighs

_____ 7 lbs.
_____ 13 lbs.
_____ 20 lbs.
_____ 33 lbs.
_____ none of the above.

9. A solid metal object is put into a large container full of water. The force that is applied to the object by the water equals the weight of

_____ all the water in the tank.
_____ the water up to the bottom of the object.
_____ the water up to the top of the object.
_____ the water that overflows.
_____ the object in water.

Part 3 - Form B

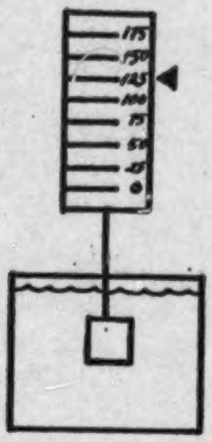
Each of several objects, while hanging from a scale, is lowered into a full tank of water. Based on the information about each object in the following table, fill in the blank spaces:

	Scale reading when object is in air	Scale reading when object is in water	Weight of water that overflows
Object #1	4 lbs.	1 lb.	
Object #2	30 lbs.		22 lbs.
Object #3		20 lbs.	10 lbs.
Object #4	20 lbs.	16 lbs.	
Object #5	35 lbs.		35 lbs.

II. PICTORIAL ITEMS

Immediate Test

1. A solid metal object is weighed while under water. The scale reads as in this picture.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75
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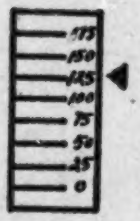
While still attached to the scale, the object is raised out of water. The most likely reading on the scale will now be: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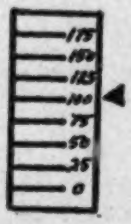
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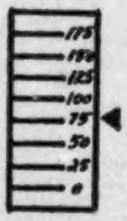
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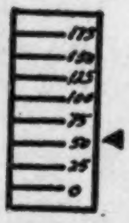
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none of these

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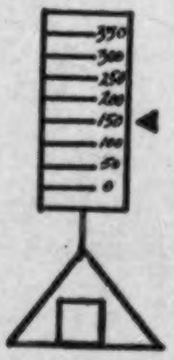
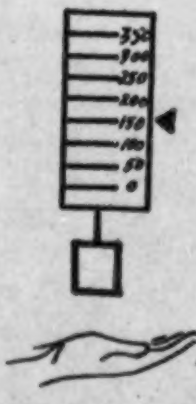
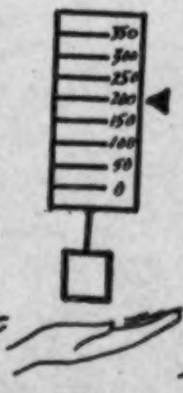
2. This is the reading for a box being weighed on a scale.


350
300
250
200
150
100
50
0

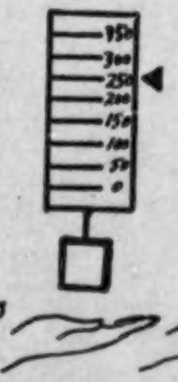
If an upward force is applied to the box, the most likely reading on the scale will be:


350
300
250
200
150
100
50
0

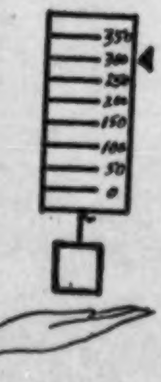
☐


350
300
250
200
150
100
50
0

☐


350
300
250
200
150
100
50
0

☐

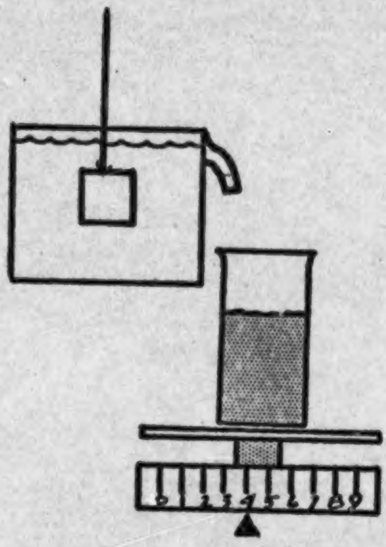

350
300
250
200
150
100
50
0

☐

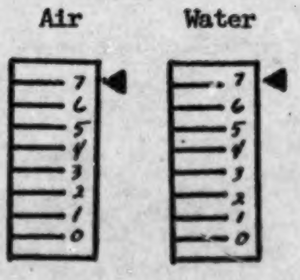
none of these

☐

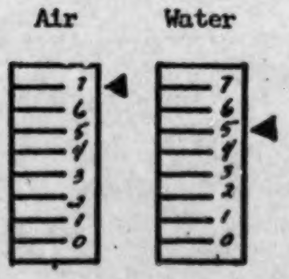
3. **When an object is lowered into water, this is what the overflow weighs.**


0 1 2 3 4 5 6 7 8 9

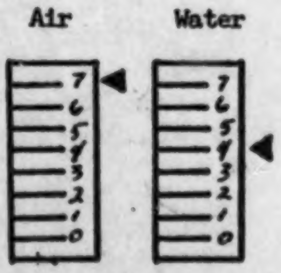
What will the scales look like for this object when weighed first in air and then in water?


Air
Water
7 6 5 4 3 2 1 0
7 6 5 4 3 2 1 0

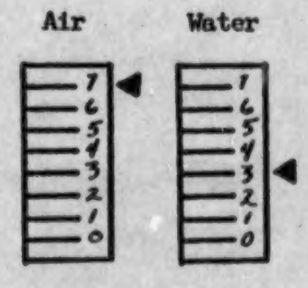
☐


Air
Water
7 6 5 4 3 2 1 0
7 6 5 4 3 2 1 0

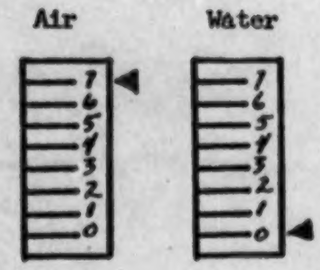
☐


Air
Water
7 6 5 4 3 2 1 0
7 6 5 4 3 2 1 0

☐

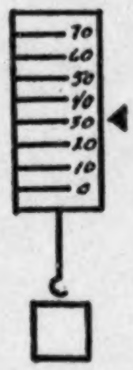

Air
Water
7 6 5 4 3 2 1 0
7 6 5 4 3 2 1 0

☐

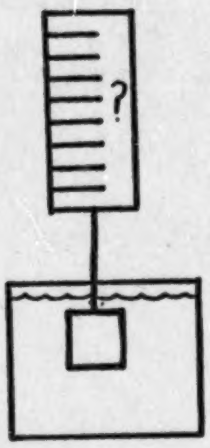

Air
Water
7 6 5 4 3 2 1 0
7 6 5 4 3 2 1 0

☐

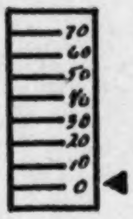
4. This is the reading on the scale for a solid metal object weighed in air.


70
60
50
40
30
20
10
0

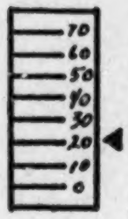
The solid metal object is lowered into water.



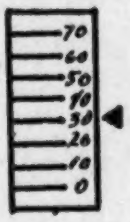
The most likely reading while in water is:


70
60
50
40
30
20
10
0

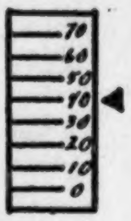
☐


70
60
50
40
30
20
10
0

☐


70
60
50
40
30
20
10
0

☐

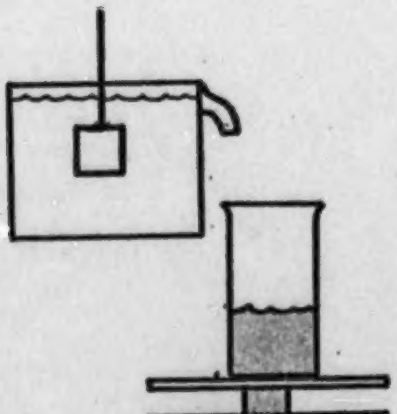

70
60
50
40
30
20
10
0

☐

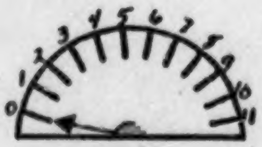
none of the above ☐

---

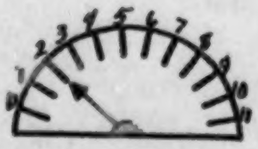
5. This is the weight of the overflow caused by a 10 lb. object lowered into a tank of water.


0 1 2 3 4 5 6 7 8 9

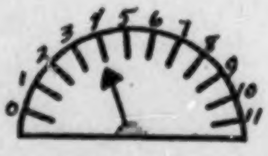
Since we can measure forces in pounds, which of the following correctly shows the force exerted by the water on the object?


0 1 2 3 4 5 6 7 8 9 10 11

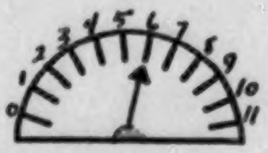
☐


0 1 2 3 4 5 6 7 8 9 10 11

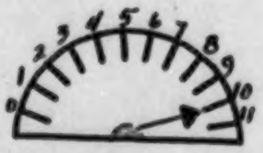
☐


0 1 2 3 4 5 6 7 8 9 10 11

☐

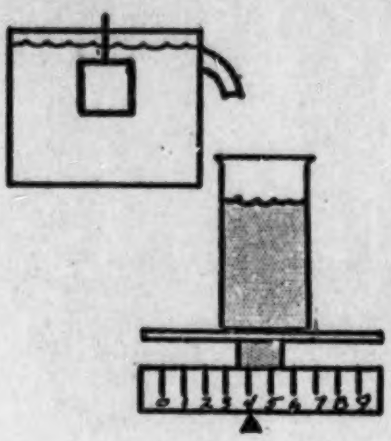

0 1 2 3 4 5 6 7 8 9 10 11

☐

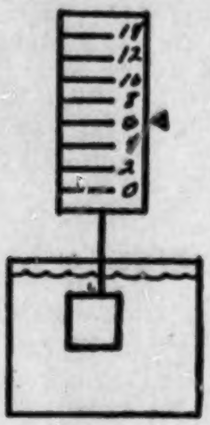

0 1 2 3 4 5 6 7 8 9 10 11

☐

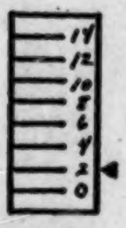
6. This is the weight of the overflow caused by an object lowered into the tank.


0 1 2 3 4 5 6 7 8 9

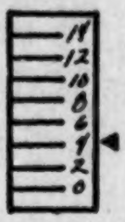
This is the weight of the object in water.


14
12
10
8
6
4
2
0

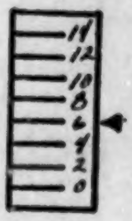
What would be the weight of this object in air?


14
12
10
8
6
4
2
0

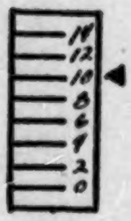
☐


14
12
10
8
6
4
2
0

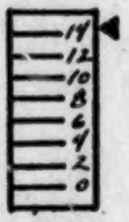
☐


14
12
10
8
6
4
2
0

☐


14
12
10
8
6
4
2
0

☐

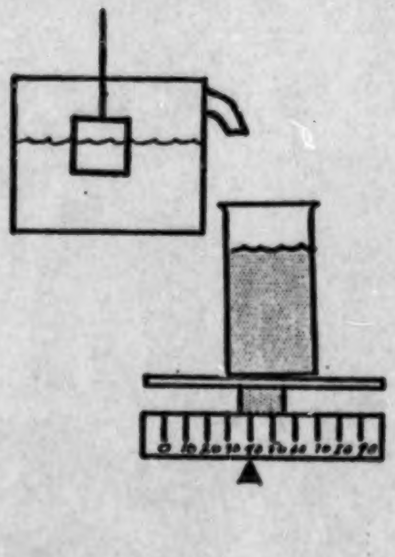

14
12
10
8
6
4
2
0

☐

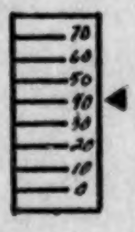
None of the above ☐

---

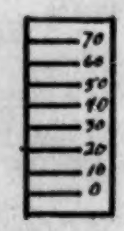
7. Weight of the overflow


0 10 20 30 40 50 60 70 80 90

Weight of the object in air.

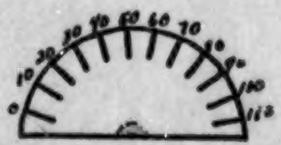

70
60
50
40
30
20
10
0

7a. What is the weight of the object in water?


70
60
50
40
30
20
10
0

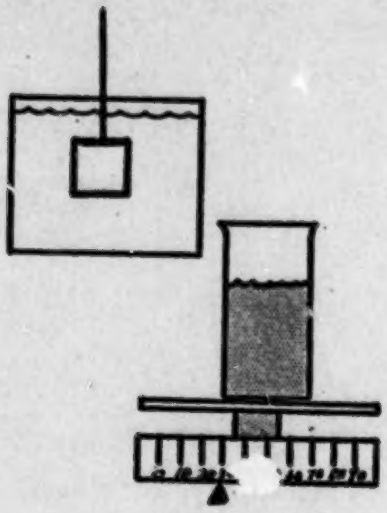
(Circle the correct number on the scale.)

7b. What is the upward force exerted by the water?

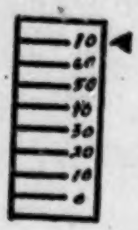

0
10
20
30
40
50
60
70
80
90
100
110

(Circle the correct number on the scale.)

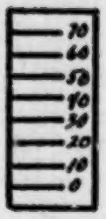
8. Weight of the overflow.



Weight of
the object
in air.

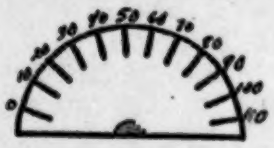

70
60
50
40
30
20
10
0

8a. What is the
weight of the
object in water?


70
60
50
40
30
20
10
0

(Circle the correct
number on the
scale.)

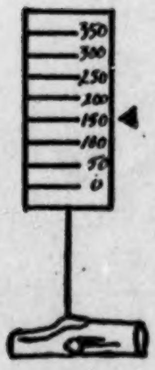
8b. What is the upward force
exerted by the water?


0
10
20
30
40
50
60
70
80
90
100
110

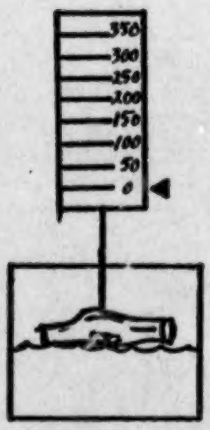
(Circle the correct number on the scale.)

9.

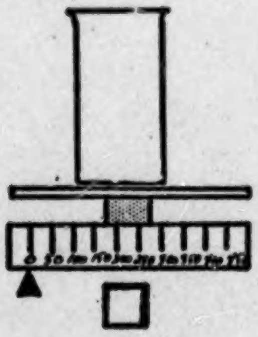
What is the weight of the overflow?


350
300
250
200
150
100
50
0

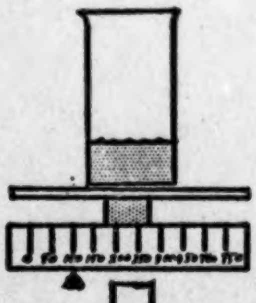
Log weighed in air.


350
300
250
200
150
100
50
0

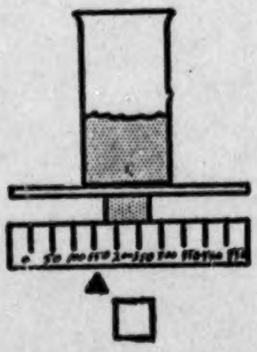
Log weighed while
floating.



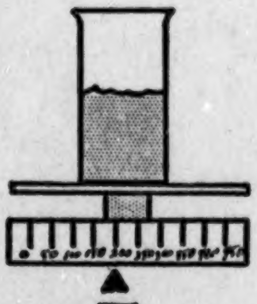
☐



☐



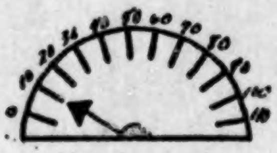
☐

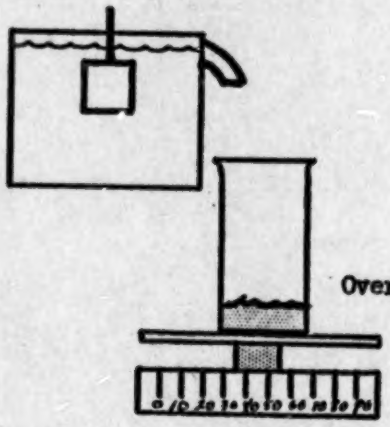


☐

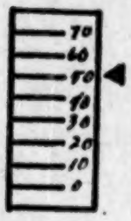
none of the above ☐

10. The force exerted by the water on the object.

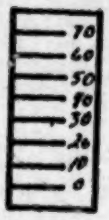

0
10
20
30
40
50
60
70
80
90
100
110


Overflow
0 10 20 30 40 50 60 70 80 90

Weight of the object in water.


70
60
50
40
30
20
10
0

9a. What will the object weigh in air?


70
60
50
40
30
20
10
0

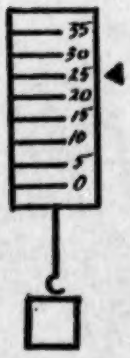
(Circle the correct number on the scale.)

9b. What will the overflow weigh?

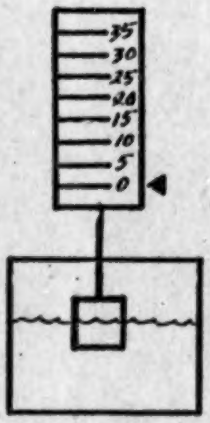
(Circle the correct number on the scale.)

---

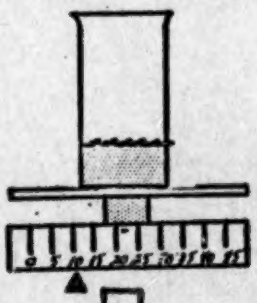
11. This is the reading on the scale for an object weighed in air.


35
30
25
20
15
10
5
0

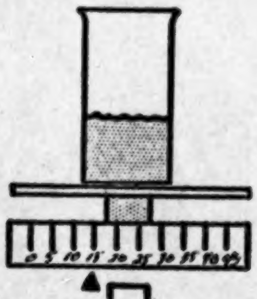
This is the reading on the scale for the same object weighed in water.


35
30
25
20
15
10
5
0

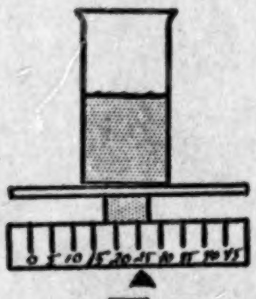
The overflow that results from this object being lowered into the tank is which of the following:


0 5 10 15 20 25 30 35 40 45

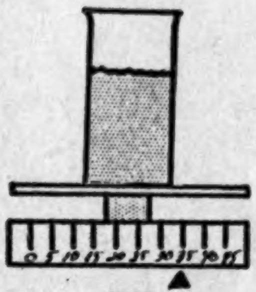
☐


0 5 10 15 20 25 30 35 40 45

☐


0 5 10 15 20 25 30 35 40 45

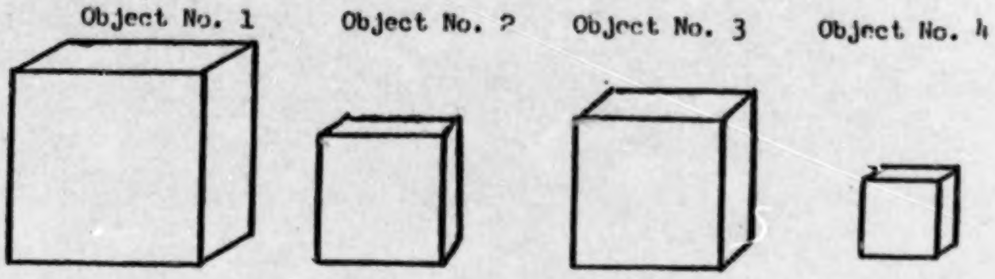
☐


0 5 10 15 20 25 30 35 40 45

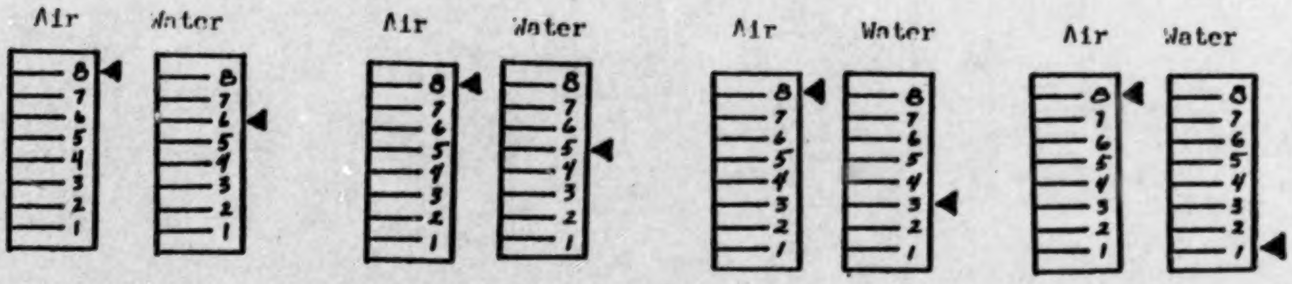
☐

none of the above ☐

12 These four objects made of different materials are first weighed in air and then weighed in water.


Object No. 1
Object No. 2
Object No. 3
Object No. 4

These are pairs of readings for the objects weighed in air and then in water.


Air
Water
Air
Water
Air
Water
Air
Water
8
7
6
5
4
3
2
1

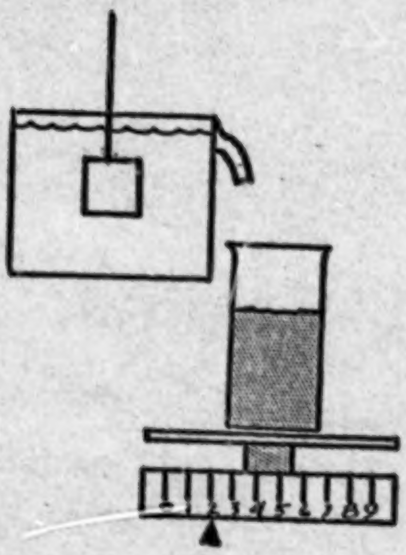
Which object goes with which pair of readings? Write in the number of the object which goes with each pair.

Object No. ____ ____ ____ ____

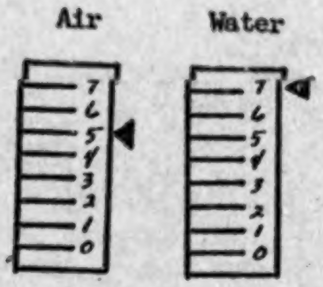
II. PICTORIAL ITEMS

Delayed Test

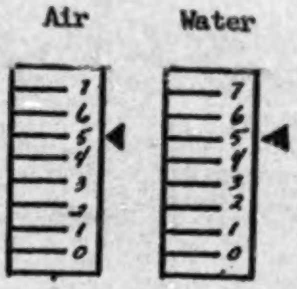
1. When an object is lowered into water, this is what the overflow weighs.



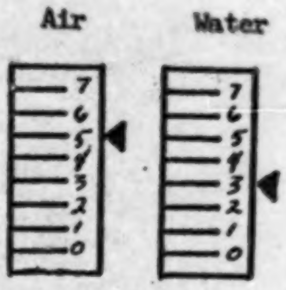
What will the scales look like for this object when weighed first in air and then in water?


Air
Water
7 6 5 4 3 2 1 0
7 6 5 4 3 2 1 0

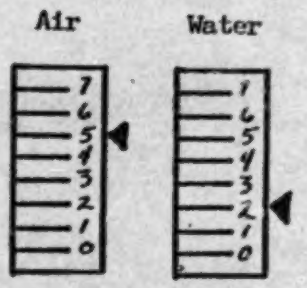
☐


Air
Water
7 6 5 4 3 2 1 0
7 6 5 4 3 2 1 0

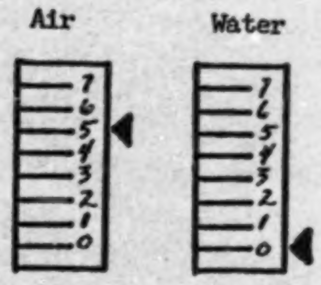
☐


Air
Water
7 6 5 4 3 2 1 0
7 6 5 4 3 2 1 0

☐

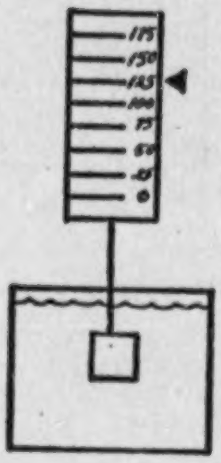

Air
Water
7 6 5 4 3 2 1 0
7 6 5 4 3 2 1 0

☐

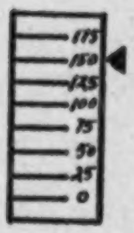

Air
Water
7 6 5 4 3 2 1 0
7 6 5 4 3 2 1 0

☐

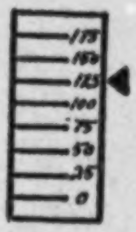
2. A solid metal object is weighed while under water. The scale reads as in this picture.


175
150
125
100
75
50
25
0

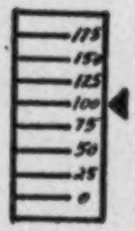
While still attached to the scale, the object is raised out of water. The most likely reading on the scale will now be:


175
150
125
100
75
50
25
0

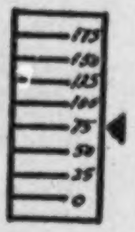
☐


175
150
125
100
75
50
25
0

☐


175
150
125
100
75
50
25
0

☐


175
150
125
100
75
50
25
0

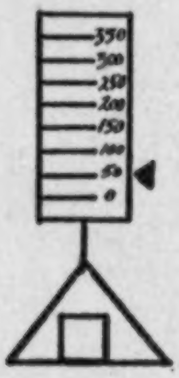
☐

none of these

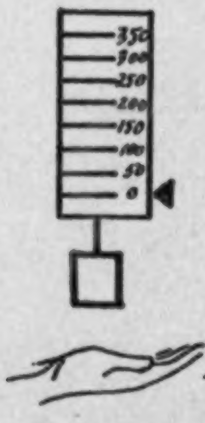
☐

---

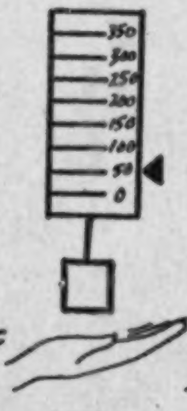
3. This is the reading for a box being weighed on a scale.


350
300
250
200
150
100
50
0

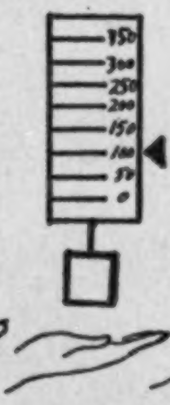
If a 50 lb. upward force is applied to the box, the most likely reading on the scale will be:


350
300
250
200
150
100
50
0

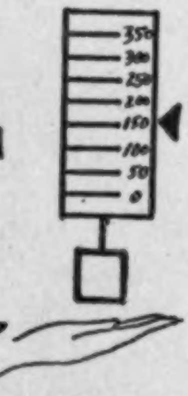
☐


350
300
250
200
150
100
50
0

☐


350
300
250
200
150
100
50
0

☐

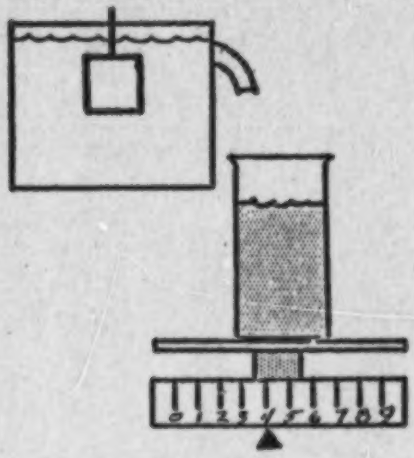

350
300
250
200
150
100
50
0

☐

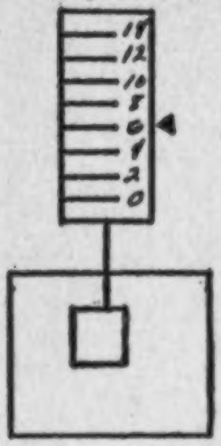
none of these

☐

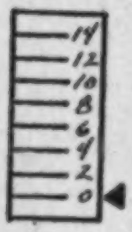
4. This is the weight of the overflow caused by an object lowered into the tank.


0 1 2 3 4 5 6 7 8 9

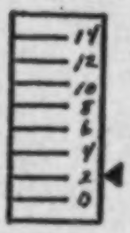
This is the weight of the object in air.


14
12
10
8
6
4
2
0

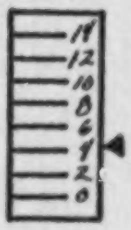
What would be the reading on the scale for this object when weighed in water?


14
12
10
8
6
4
2
0

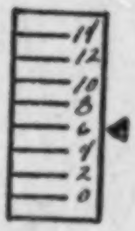
☐


14
12
10
8
6
4
2
0

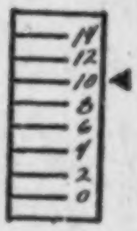
☐


14
12
10
8
6
4
2
0

☐


14
12
10
8
6
4
2
0

☐


14
12
10
8
6
4
2
0

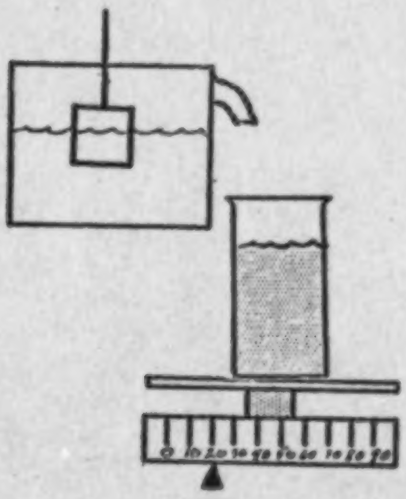
☐

None of these

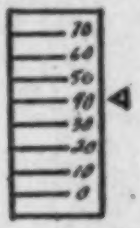
☐

---

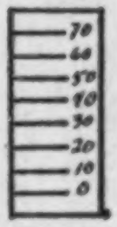
5. Weight of the overflow


0 10 20 30 40 50 60 70 80 90

Weight of the object in air.

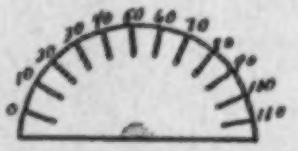

70
60
50
40
30
20
10
0

5a. What is the weight of the object in water?


70
60
50
40
30
20
10
0

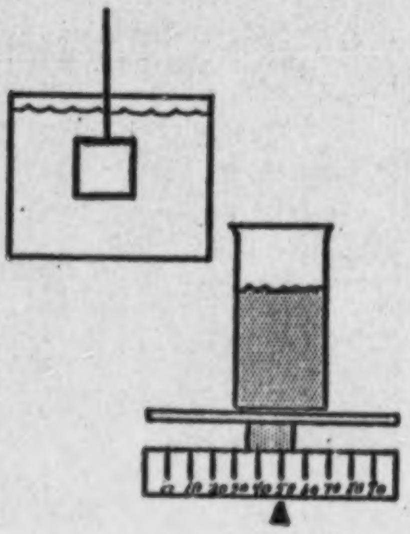
(Circle the correct number on the scale.)

5b. What is the upward force exerted by the water?

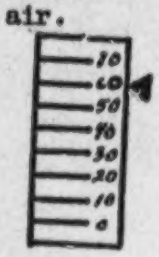

0 10 20 30 40 50 60 70 80 90 100 110

(Circle the correct number on the scale.)

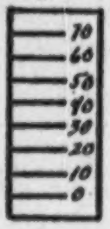
6. **Weight of the overflow.**


0
10
20
30
40
50
60
70
80
90

Weight of the object in air.

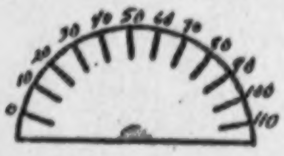

70
60
50
40
30
20
10
0

6a. **What is the weight of the object in water?**


70
60
50
40
30
20
10
0

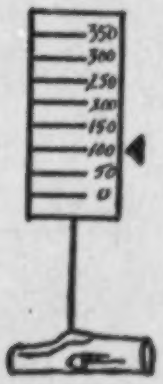
(Circle the correct number on the scale.)

6b. **What is the upward force exerted by the water?**

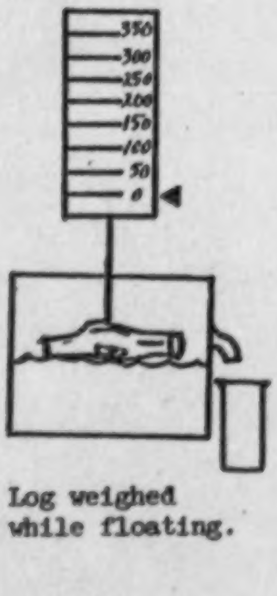

0
10
20
30
40
50
60
70
80
90
100
110

(Circle the correct number on the scale.)

7.

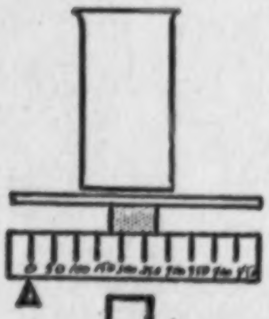

350
300
250
200
150
100
50
0

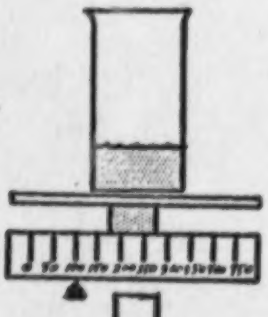
Log weighed in air.

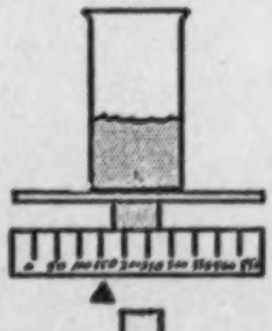

350
300
250
200
150
100
50
0

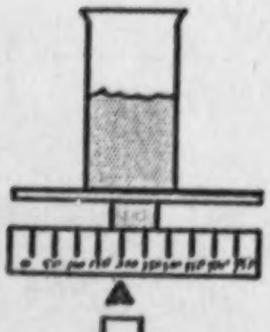
Log weighed while floating.

What is the weight of the overflow?


☐

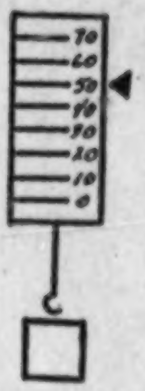

☐


☐

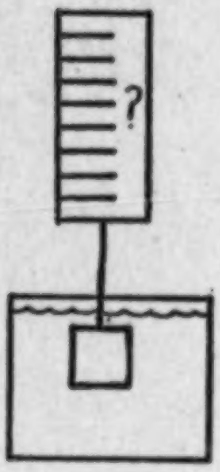

☐

none of the above ☐

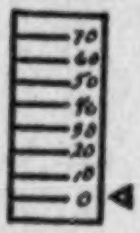
8. This is the reading on the scale for a solid metal object weighed in air.


70
60
50
40
30
20
10
0

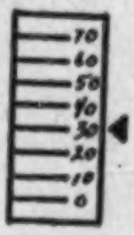
The solid metal object is lowered into water.



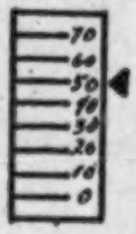
The most likely reading while in water is:


70
60
50
40
30
20
10
0

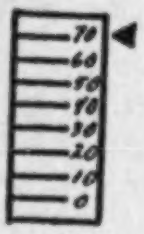
☐


70
60
50
40
30
20
10
0

☐


70
60
50
40
30
20
10
0

☐

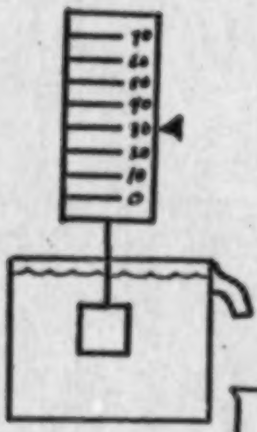

70
60
50
40
30
20
10
0

☐

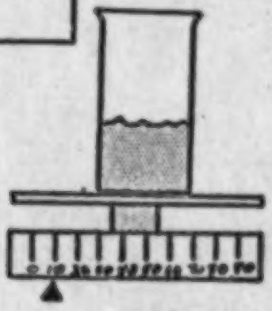
none of the above ☐

---

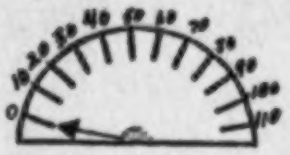
9. This is the reading on a scale for an object weighed in water.


70
60
50
40
30
20
10
0

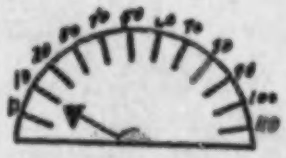
This is the weight of the overflow caused by the object lowered into a tank of water.


0 10 20 30 40 50 60 70 80 90

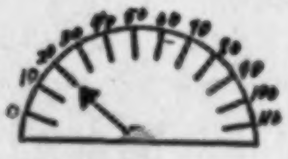
Since we can measure forces in pounds, which of the following correctly shows the force exerted by the water on the object?


0 10 20 30 40 50 60 70 80 90 100 110

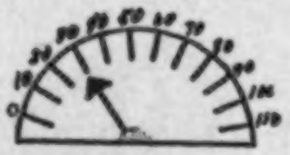
☐


0 10 20 30 40 50 60 70 80 90 100 110

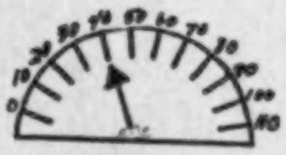
☐


0 10 20 30 40 50 60 70 80 90 100 110

☐

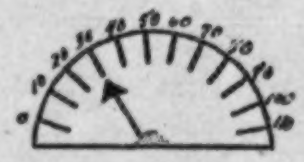

0 10 20 30 40 50 60 70 80 90 100 110

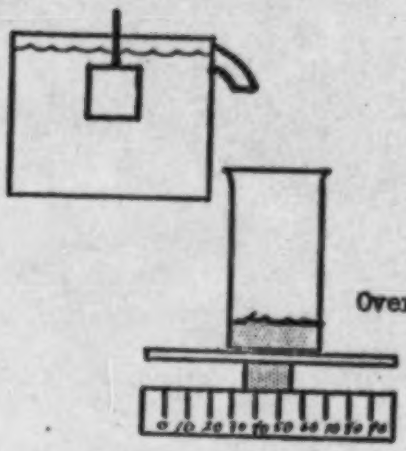
☐


0 10 20 30 40 50 60 70 80 90 100 110

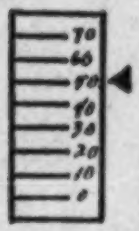
☐

10. The force exerted by the water on the object.

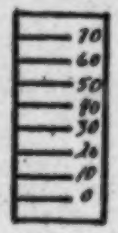




Weight of the object in air.


70
60
50
40
30
20
10
0

10a. What will the object weigh in water?


70
60
50
40
30
20
10
0

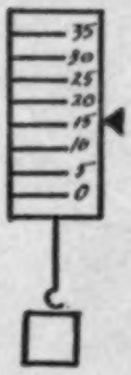
(Circle the correct number on the scale.)

10b. What will the overflow weigh?

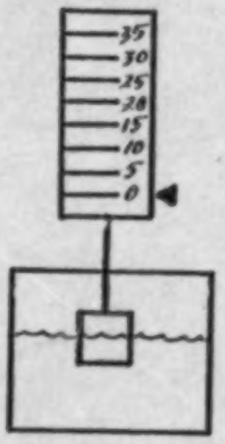
(Circle the correct number on the scale.)

---

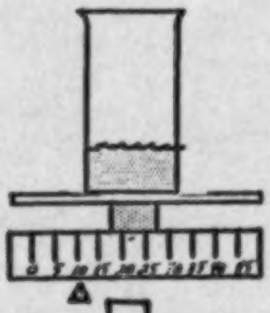
11. This is the reading on the scale for an object weighed in air.

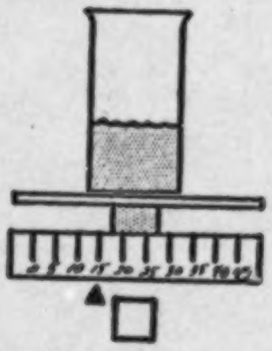

35
30
25
20
15
10
5
0

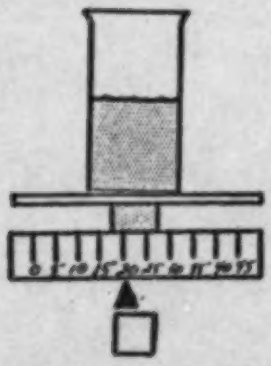
This is the reading on the scale for the same object weighed in water.

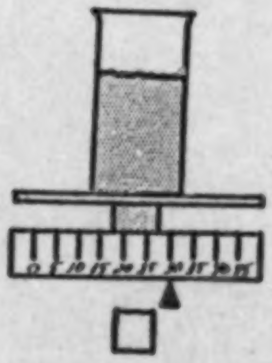

35
30
25
20
15
10
5
0

The overflow that results from this object being lowered into the tank is which of the following:


☐


☐

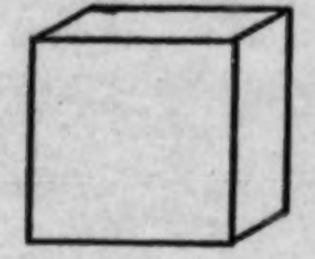

☐


☐

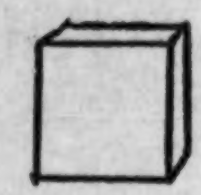
none of the above ☐

12. These four objects made of different materials are first weighed in air and then weighed in water.

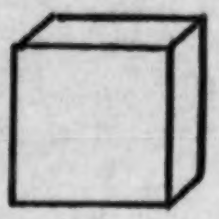
Object No. 1



Object No. 2



Object No. 3



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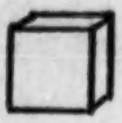
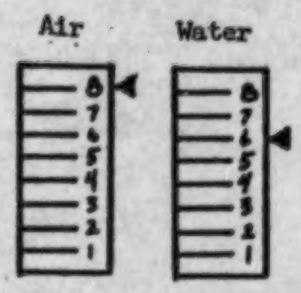


These are pairs of readings for the objects weighed in air and then in water.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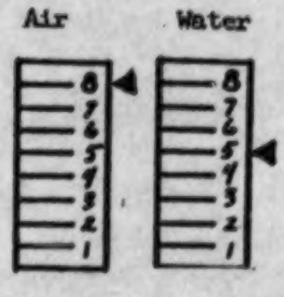
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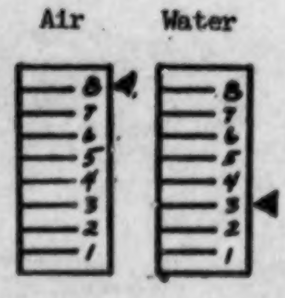
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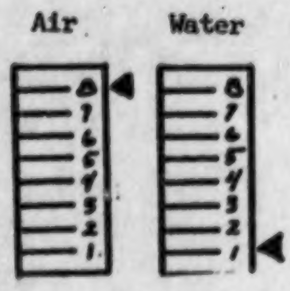
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Which object goes with which pair of readings? Write in the number of the object which goes with each pair.

Object No. ____ ____ ____ ____

Study No. 1

APPENDIX D
ADDITIONAL RESULTS

Table 1

Analysis of Variance
Comparing TOTAL Test Scores for
Groups Receiving Visual or Verbal Programs

	Sums of Squares	df	Mean Square	F
Type of Program	9.11	1	9.11	.41
IQ	.61	1	.61	.03
Type of Program x IQ	59.52	1	59.52	2.69
Within	1678.65	76	22.09	

Table 2

Analysis of Variance
Comparing VISUAL Test Scores for
Groups Receiving Visual or Verbal Programs

	Sums of Squares	df	Mean Square	F
Type of Program	39.20	1	39.20	4.55*
IQ	.45	1	.45	.05
Type of Program x IQ	.45	1	.45	.05
Within	654.10	76	8.61	

*significance at the 5% level

Table 3

Analysis of Variance
Comparing VERBAL Test Scores on the Immediate Posttest for Groups Receiving Visual and Verbal Programs in Different Orders

	Sums of Squares	df	Mean Square	F
Order of Presentation	113.86	3	37.95	2.91*
IQ	28.57	1	28.57	2.19
Order x IQ	37.86	3	12.62	.97
Within	625.14	48	13.02	

***significance at the 5% level**

Table 4

Analysis of Variance
Comparing VERBAL Test Scores on the Delayed Test for Groups Receiving Visual and Verbal Programs in Different Orders

	Sums of Squares	df	Mean Square	F
Order of Presentation	58.50	3	19.50	1.14
IQ	.29	1	.29	.02
Order x IQ	60.57	3	20.19	1.18
Within	818.86	48	17.06	

Table 5

Analysis of Variance
Comparing TOTAL Test Scores on the Immediate Posttest for Groups Receiving Programs in Visual/Verbal and Verbal/Visual Order of Presentation

	Sums of Squares	df	Mean Square	F
Order of Presentation	97.52	1	97.52	5.75*
Residual	339.48	20	16.97	

***significance at the 5% level**

Table 6

Analysis of Variance
Comparing TOTAL Test Scores on the Delayed Posttest (2 weeks) for Groups Receiving Programs in Visual/Verbal and Verbal/Visual Orders of Presentation

	Sums of Squares	df	Mean Square	F
Order of Presentation	27.52	1	27.52	3.52
Residual	156.48	20	7.82	

Table 7

Analysis of Variance
Comparing TOTAL Test Scores on the Delayed Posttest (4 months) for Groups Receiving Programs in Visual/Verbal and Verbal/Visual Orders of Presentation

	Sums of Squares	df	Mean Square	F
Order of Presentation	26.03	1	26.03	1.57
Residual	215.47	20	16.57	

Table 8

Analysis of Variance
Comparing VERBAL Test Scores on the Immediate Posttest for Groups Receiving Programs in Visual/Verbal and Verbal/Visual Orders of Presentation

	Sums of Squares	df	Mean Square	F
Order of Presentation	61.93	1	61.93	5.19*
Residual	238.57	20	11.93	

*significance at the 5% level

Table 9

Analysis of Variance
Comparing VERBAL Test Scores on the Delayed Posttest (2 weeks) for Groups Receiving Programs in Visual/Verbal and Verbal/Visual Orders of Presentation

	Sums of Squares	df	Mean Square	F
Order of Presentation	44.02	1	44.02	1.97
Residual	447.48	20	22.37	

Table 10

Analysis of Variance
Comparing VERBAL Test Scores on the Delayed Posttest (4 months) for Groups Receiving Programs in Visual/Verbal and Verbal/Visual Orders of Presentation

	Sums of Squares	df	Mean Square	F
Order of Presentation	57.14	1	57.14	5.69*
IQ	41.29	1	41.29	4.11
Order x IQ	20.57	1	20.57	2.05
Within	240.86	24	10.04	

***significance at the 5% level**

Table 11

Analysis of Variance
of Gain Scores on VERBAL Items
for Active Response and Non-Active Response Groups
(Test Administered After Visual Presentation)

	Sums of Squares	df	Mean Square	F
Mode of Response	49.00	1	49.00	4.71*
IQ	4.39	2	2.20	.21
Mode x IQ	3.17	2	1.58	.15
Within	312.00	30	10.40	

***significance at the 5% level**

Table 12

Analysis of Variance of Gain Scores on VERBAL Items for Active Response and Non-Active Response Groups (Immediate Posttest)

	Sums of Squares	df	Mean Square	F
Mode of Response	23.36	1	23.36	3.11
IQ	20.05	2	10.02	1.34
Mode x IQ	2.39	2	1.20	.16
Within	225.17	30	7.50	

Table 13

Analysis of Variance of Gain Scores on VERBAL Items for Active Response and Non-Active Response Groups (2-Week Delayed Test)

	Sums of Squares	df	Mean Square	F
Mode of Response	66.69	1	66.69	7.61**
IQ	7.39	2	3.70	.42
Mode x IQ	2.06	2	1.03	.12
Within	262.83	30	8.76	

****significance at the 1% level**

Table 14

Analysis of Variance of Gain Scores on VERBAL Items for Active Response and Non-Active Response Groups (4-Month Delayed Test)

	Sums of Squares	df	Mean Square	F
Mode of Response	70.04	1	70.04	11.32**
IQ	5.04	1	5.04	.81
Mode x IQ	.05	1	.05	.008
Within	123.83	20	6.19	

****significance at the 1% level**

APPENDICES

Study No. 2 - Pressure

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APPENDIX B - Visual Workbooks B-1 - B-5

APPENDIX C - Achievement Test C-1 - C-2

APPENDIX D - Additional Results D-1 - D-4

APPENDIX A

VERBAL LESSON ON PRESSURE*

Section 1

1.

A scale goes down when you push it down with your hand.
A mattress sags when you PUSH it DOWN with your hand.

2.

If you push a scale down with your hand, we say that you are applying a downward force to the scale.
If you push a mattress down with your hand, you are APPLYING a downward FORCE to the mattress.

3.

If you push a mattress down with your hand, you are APPLYING a downward FORCE to the mattress.
If you sit on the mattress, the weight of your body is also APPLYING a DOWNWARD FORCE to the mattress.

4.

A mattress sags when you lie on it, because your weight applies a DOWNWARD FORCE to the MATTRESS.

5.

A scale goes down when you stand on it, because your weight applies a DOWNWARD FORCE to the SCALE.

6.

You can get more clothes in a suitcase, if you apply a strong downward force to the clothes.
You can get more laundry in a hamper, if you APPLY a STRONG downward force to the laundry.

7.

A heavy box pushes down hard on a table and we therefore say that it applies a STRONG downward force to the table.
Any heavy object on the table also APPLIES a STRONG downward force to the TABLE.

8.

The more an object weighs, the stronger the DOWNWARD FORCE it is applying to the floor.
The more a man weighs, the STRONGER the DOWNWARD FORCE he is applying to the floor.

9.

It is more difficult to carry seven books in your arms than two books because the seven books apply a STRONGER downward FORCE to your arms than the two books.

10.

A 200 lb. man pushes a bed down farther than a 130 lb. man, because the 200 lb. man applies a STRONGER DOWNWARD FORCE to the BED.

11.

An object which only weighs a little applies a weak downward force.
A feather on a table APPLIES a WEAK downward force to the TABLE.

12.

A heavy object applies a strong downward force to a table.
But, a spoon weighing only a few ounces APPLIES a WEAK downward force to the TABLE.

---

*Subjects made constructed responses for each of the following frames. The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. The correct constructed responses appear in capital letters.

13.

The less an object weighs the WEAKER the DOWNWARD FORCE it is applying.
A 30 lb. suitcase applies a WEAKER downward force than a 50 lb. suitcase.

14.

The weight of a lamp standing on a rug determines how strong a DOWNWARD FORCE the lamp applies to the RUG.
The weight of a sofa on the floor determines how STRONG a DOWNWARD FORCE the sofa applies to the FLOOR.

15.

We measure how strong a force is in lbs.
An object weighing 25 lbs. applies a downward force of 25 lbs. to a table.
A 40 lb. box on a table APPLIES A DOWNWARD FORCE of 40 lbs. to the TABLE.

16.

A 350 lb. box on a loading platform applies a DOWNWARD FORCE of 350 LBS. to the LOADING PLATFORM.

17.

The downward force which you apply to the floor depends on how much you WEIGH.
The objects which apply the strongest downward force are the ones which WEIGH the MOST.

18.

How strong a downward force objects apply to any surface depends on HOW MUCH THE OBJECTS WEIGH.

Section 2

19.

A football field has a large playing area.
But, a tennis court only has a SMALL playing AREA.

20.

If many people were bunched up in a small elevator, we would say that they are concentrated in a small area.
If many students got into a corner, we would also say that they are CONCENTRATED in a small AREA.

21.

If several people tried to get into a telephone booth, they would be CONCENTRATED in a SMALL area.
Anytime we put a lot of things on the same shelf, they would be CONCENTRATED in a SMALL AREA.

22.

When students sit in all parts of the room, they are spread over a large area.
Ice skaters in all parts of a rink are SPREAD over a LARGE area.

23.

Marbles all over the floor are SPREAD over a LARGE AREA.
But, if they are in a bag they are CONCENTRATED in a SMALL AREA.

24.

A refrigerator can be standing upright or be tipped over and lying on its side.
Either way, it weighs the same.
A man standing up or lying down also WEIGHS the SAME.

25.

No matter what position an object is in, the object weighs the SAME.
Therefore, no matter what position the object is in, the object still applies the SAME downward force.

26.

No matter what position it is in, a 175 lb. regrigerator applies a downward force of 175 lbs.
Whether the refrigerator is standing upright or lying on its side, it still applies the SAME downward force.

27.

A refrigerator standing upright covers a small area of the floor.
If the refrigerator is tipped over and is lying on its side, it would cover up a LARGE area of the FLOOR.

28.

An object can apply a downward force which is concentrated on a SMALL AREA of the floor.
A regrigerator standing upright applies a downward force which is CONCENTRATED on a SMALL AREA of the floor.

29.

An object can apply a downward force which is spread over a LARGE AREA.
When a refrigerator is lying on its side, its weight applies a downward force which is SPREAD over a LARGE AREA of the floor.

30.

The same refrigerator always applies the SAME downward force.
When the refrigerator is standing up, the downward force is concentrated on a SMALL AREA.
When it is lying down, the downward force is still the SAME, but it is now spread over a LARGE AREA.

31.

If 250 students crowded into a small classroom, their weight would apply a downward force which is CONCENTRATED on a SMALL area.
If the same 250 students entered a large auditorium, their weight would still apply the SAME downward force.
But the downward force would now be SPREAD OVER A LARGE AREA.

32.

The same object always applies the SAME DOWNWARD FORCE.
Sometimes the downward force is spread over a LARGE AREA.
Other times the SAME downward force is CONCENTRATED on a SMALL AREA.

Section 3

33.

When we want to talk about the whole area, we would say the total area.
Similarly, when we talk about the whole force we would say the TOTAL force.

34.

Anytime we want to talk about the whole amount of force being applied, we use the words TOTAL FORCE.

35.

If 25 lbs. of force were being applied, we could say that a TOTAL FORCE of 25 LBS. was being applied.

36.

Just as we can talk of a total force, we can also talk of a TOTAL area.
The bottom of a box has a TOTAL AREA of 30 square inches.

37.

The bottom of box A has a TOTAL AREA of 55 square inches.
The bottom of box B has a TOTAL AREA of 20 SQUARE INCHES.

38.

An elevator floor measures 1500 square inches.
The number of square inches tells us that the elevator floor has a TOTAL AREA of 1500 SQUARE INCHES.

39.

The bottom of a box measures 65 square inches.
The number of square inches tells us that the bottom of the box has a TOTAL AREA OF 65 SQUARE INCHES.

40.

The words "total force" are used when we want to indicate that the whole amount of force is being applied to the TOTAL area.

41.

"Total force" always indicates that the whole amount of force is being applied to the TOTAL AREA.

42.

80 lbs. of flour is spread on the bottom of a box which has a total area of 40 square inches.
80 lbs. is the TOTAL FORCE which is being applied to the bottom of the box.
This force is being applied to a TOTAL AREA of 40 square inches.

43.

90 lbs. of sand covers the bottom of a box which measures 30 square inches.
90 lbs. is the TOTAL FORCE which is being applied to the whole bottom of the box.
This force is being applied to a TOTAL AREA of 30 SQUARE INCHES.

44.

Sometimes we want to know how much force is being applied to each square inch of the total area.
Pressure tells us how much force is applied to EACH square inch of the TOTAL AREA.

45.

Pressure tells us how MUCH force is being applied to EACH square inch of the TOTAL AREA.

46.

Pressure tells us HOW MUCH force is being APPLIED to EACH square inch of the TOTAL AREA.

47.

Total force tells us that the whole force is being applied to the TOTAL AREA.
But pressure tells us HOW MUCH FORCE IS BEING APPLIED TO EACH SQUARE INCH OF THE TOTAL AREA.

48.

Pressure of 30 lbs./sq. inch -- may be read as -- pressure of 30 lbs. per square inch.
Pressure of 4 lbs./sq. inch -- may be read as PRESSURE OF 4 LBS. PER SQUARE INCH.

49.

Pressure of 10 lbs./sq. inch reads PRESSURE OF 10 LBS. PER SQUARE INCH.
It means that there is a force of 10 LBS. on EACH SQUARE INCH.

50.

Pressure of 15 lbs. per square inch means there is a force of 15 LBS. ON EACH SQUARE INCH.
Pressure of 45 lbs. per square inch means that there is a FORCE of 45 LBS. on EACH SQUARE INCH.

51.

Pressure of 25 lbs. per square inch means that THERE IS A FORCE OF 25 LBS. ON EACH SQUARE INCH.

52.

If there were a total of 15 apples to be divided among 5 boys, there would be 3 apples for each boy.
If there were a total force of 15 lbs. applied to a total area of 5 square inches, there would be a force of 3 lbs. on EACH square inch.

53.

If a total force of 36 lbs. is applied to a total area of 9 square inches, there would be a FORCE of 4 lbs. on EACH SQUARE INCH.

54.

Dividing the total force by the total area, we can figure out how MUCH force is applied to EACH SQUARE INCH.

55.

Pressure tells us HOW MUCH FORCE IS APPLIED TO EACH SQUARE INCH.
If we divide the total force by the total area, we are able to find out HOW MUCH FORCE IS APPLIED TO EACH SQUARE INCH.
Therefore, this tells us what the PRESSURE is.

56.

Here is the formula for figuring out pressure

$$P = \frac{F}{A}$$

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

The formula $P = \frac{F}{A}$
stands for: $\text{Pressure} = \frac{\text{FORCE}}{\text{AREA}}$

57.

The letters in the formula $P = \frac{F}{A}$ stand for:

$\text{PRESSURE} = \frac{\text{FORCE}}{\text{AREA}}$.

58.

The formula for figuring out pressure just using the first letters of each word is:
$P = \frac{F}{A}$.

59.

Force = 12 lbs. Area = 4 square inches
The pressure is $\frac{12}{4} = 3$ lbs. per square inch.

Force = 35 lbs. Area = 5 square inches
The pressure is 7 LBS. per SQUARE INCH.

60.

A total force of 18 lbs. is applied to a total area of 3 square inches.
The pressure is 6 LBS. PER SQUARE INCH.

61.

Flour applies a total downward force of 100 lbs. to the bottom of a box which has a total area of 25 square inches.
A total force of 100 LBS. is applied to a total area of 25 SQUARE INCHES.
The pressure is 4 LBS. per SQUARE INCH.

62.

We can tell how much total force is applied to the TOTAL AREA.
Pressure tells us how much force there is on EACH SQUARE INCH of the TOTAL area.

63.

We usually talk about the amount of total force on a TOTAL AREA.
On the other hand, we usually talk about pressure when we want to know about the FORCE on EACH SQUARE INCH of the TOTAL AREA.

Section 4

64.

Each time you push the same button, you are applying a force to the same total area.
Each time you hit the same nail, you are applying a FORCE to the SAME TOTAL AREA.

65.

Each time you sit on the same chair you are applying a force to the SAME TOTAL AREA.
Each time you lie on your bed you are APPLYING A FORCE TO THE SAME TOTAL AREA.

66.

There is an increase in pressure when the force applied to the SAME total area gets stronger.
There is an increase in pressure on a nail when the FORCE applied to the SAME nail gets STRONGER.

67.

Each time you push the same button, the pressure on the button depends on how STRONG a force you APPLY to the same BUTTON.

68.

How high the pressure on an area is depends on HOW STRONG A FORCE YOU APPLY TO THE SAME TOTAL AREA.

69.

Pressure

1) The areas in the three different examples all have the same total area.

$\frac{4 \text{ lb. force}}{2 \text{ sq. inches}}$ = 2 lbs./sq. in.

$\frac{8 \text{ lb. force}}{2 \text{ sq. inches}}$ = 4 lbs./sq. in.

$\frac{12 \text{ lb. force}}{2 \text{ sq. inches}}$ = 6 lbs./sq. in.

2) There is an increase in pressure when there is an INCREASE in the force applied to the SAME total AREA.

70.

There is an increase in pressure when there is an INCREASE in the FORCE applied to the SAME total area.

71.

Force of $\frac{12 \text{ lbs.}}{3 \text{ sq. in.}}$ = pressure of 4 lbs./sq. in.

Force of $\frac{6 \text{ lbs.}}{3 \text{ sq. in.}}$ = pressure of 2 lbs./sq. in.

Force of $\frac{3 \text{ lbs.}}{3 \text{ sq. in.}}$ = pressure of 1 lb./sq. in.

Force can increase and can also decrease.
There is a decrease in pressure when there is also a DECREASE in the force applied to the SAME TOTAL AREA.

72.

There is an increase of pressure when there is an INCREASE in the FORCE applied to the SAME TOTAL AREA.
There is a decrease in pressure when there is a DECREASE in the FORCE applied to the SAME TOTAL AREA.

73.

If the total area remains the same, pressure increases or decreases depending on whether THE FORCE INCREASES OR DECREASES.

74.

A lot of people on the same elevator apply a DOWNWARD FORCE to the elevator floor.
If a few people get out, the downward force on the same elevator floor DECREASES and the pressure therefore also DECREASES.

75.

As more people crowd into an elevator the downward force applied to the same elevator floor INCREASES.
The pressure on the elevator floor therefore also INCREASES.

Section 5

76.

If too many skaters crowd onto one part of a frozen lake, the ice breaks because the pressure on the ice gets too high.
The ice breaks when the PRESSURE on it gets too HIGH.

77.

If too many trucks get on a bridge at the same time, the bridge will break if the PRESSURE becomes too HIGH.

78.

The ice breaks when the PRESSURE on the ice becomes too HIGH.
Anytime all the downward force due to people's weight is concentrated on a small area, the PRESSURE on the area becomes HIGH.

79.

When the downward force due to people's weight is concentrated on a small area of the ice, the ice may break if the PRESSURE on that AREA becomes too HIGH.

80.

If ice skaters crowd into one corner of a rink, all the downward force is CONCENTRATED on a SMALL area.
The ice breaks because the PRESSURE on that AREA gets too HIGH.

81.

When people skate all over a frozen lake, the downward force is NOT concentrated on a small area.
Therefore, the PRESSURE will NOT be high.

82.

Pressure can be high or low.
A mattress will sag when pressure on it is HIGH.
A mattress will not sag as much when the PRESSURE on it is LOW.

83.

Pressure is low when a downward force is spread over a LARGE AREA.
But, pressure is high when the downward force is CONCENTRATED on a SMALL AREA.

84.

All the students in a school tried to get on the stage in the auditorium at the same time.
The pressure on the stage became too HIGH, because all the downward FORCE was CONCENTRATED ON A SMALL AREA.

85.

All the students sit in chairs in different parts of an auditorium.
The pressure on the floor is LOW, because THE DOWNWARD FORCE IS SPREAD OVER A LARGE AREA.

86.

A force can be spread over a large area. Sometimes the same force can be concentrated on smaller and smaller areas. When the area gets smaller the pressure becomes HIGHER.

87.

$\frac{\text{12 lb. force}}{\text{12 square inches}}$ = 1 lb./sq. inch

$\frac{\text{12 lb. force}}{\text{6 square inches}}$ = 2 lbs./sq. inch

$\frac{\text{12 lb. force}}{\text{4 square inches}}$ = 3 lbs./sq. inch

When force remains the same, there is an increase in pressure as the area DECREASES.

88.

When force applied remains the same, there is an increase in pressure as THE AREA DECREASES. However, there will be a decrease in pressure as the area INCREASES.

89.

If the force applied remains the same, pressure decreases as THE AREA INCREASES.

90.

A log can be standing on end or lying on its side. Higher pressure is produced on the ground when the log is STANDING ON END, because that way the DOWNWARD FORCE is CONCENTRATED ON A SMALLER AREA.

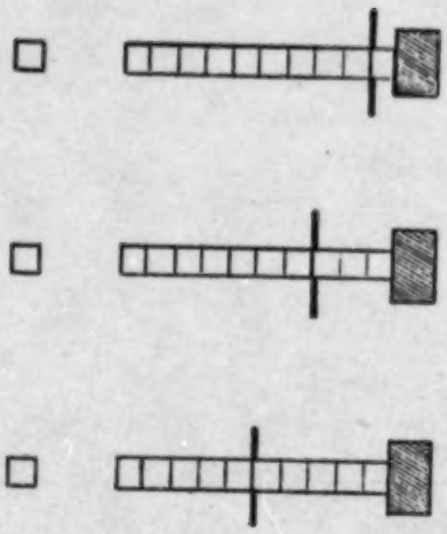
91.

When a man uses snowshoes he doesn't sink into deep snow. When he uses snowshoes the downward force due to his weight is the same as when he wears ordinary shoes, but it is SPREAD OVER A LARGE AREA. As a result the PRESSURE on the snow is LOWER.

APPENDIX B

RESPONSE WORKBOOKS FOR LESSON ON PRESSURE

I. VISUAL DISCRIMINATIONS



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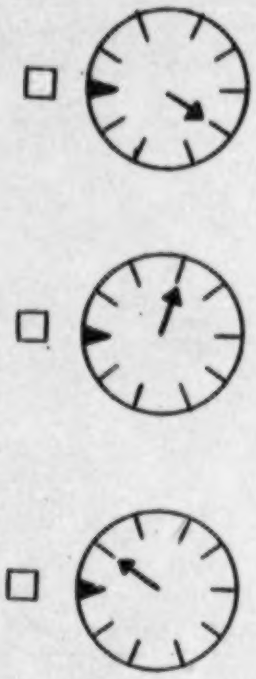

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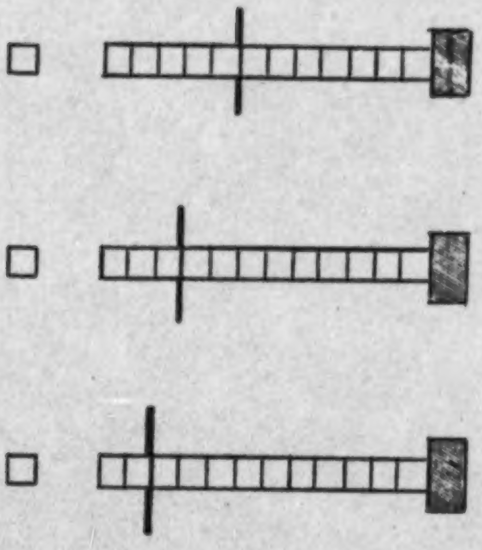

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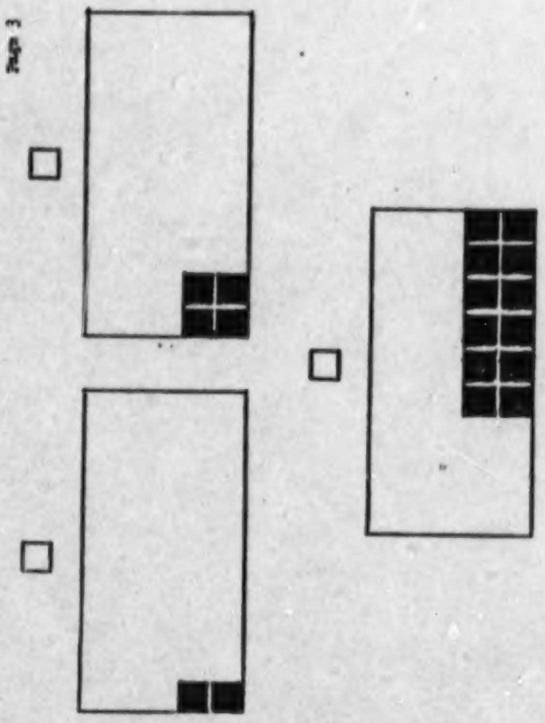

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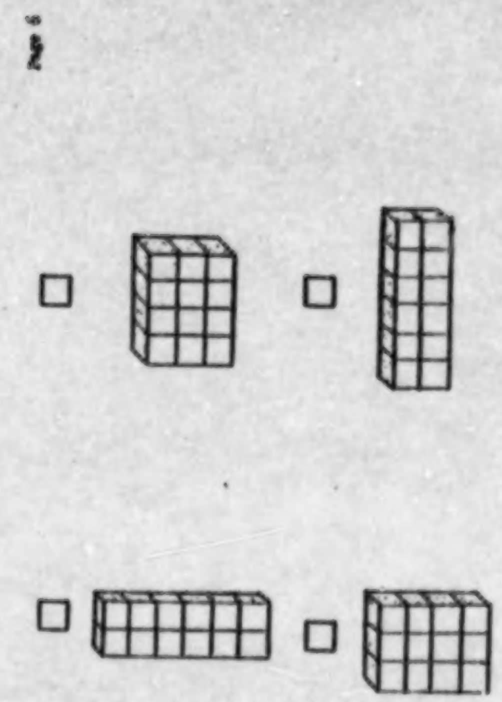
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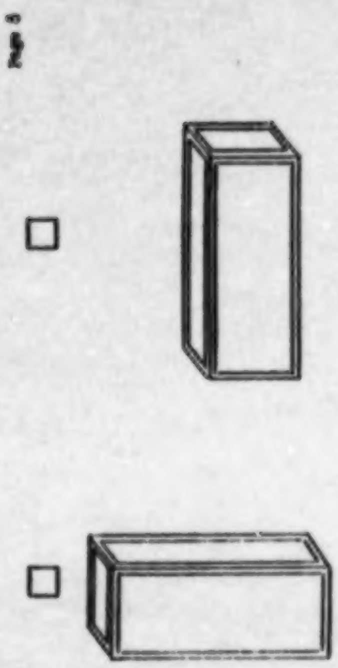
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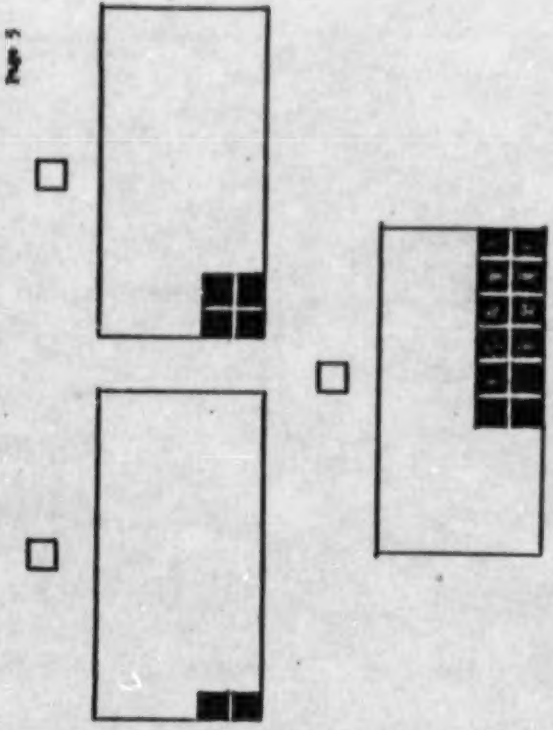
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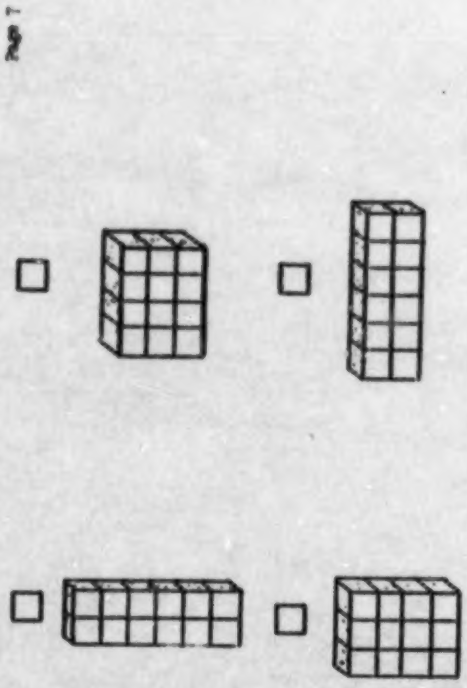
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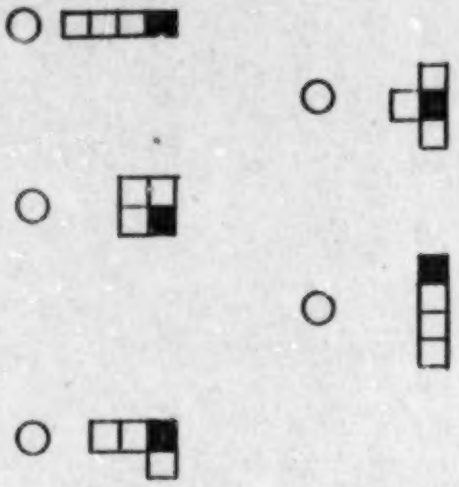

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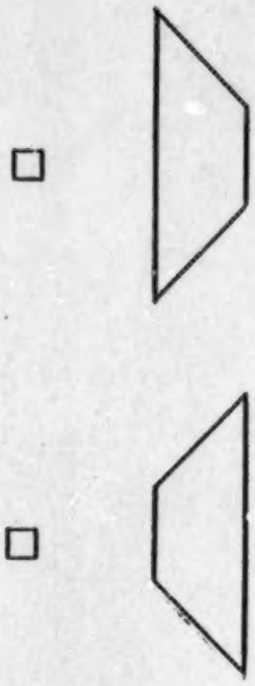

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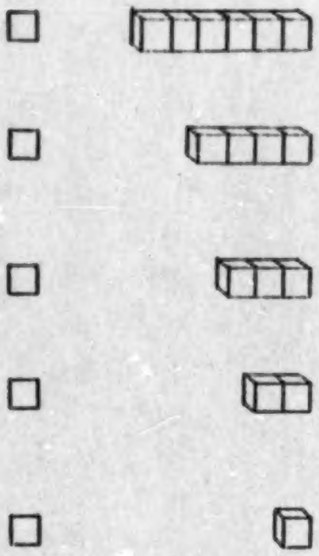

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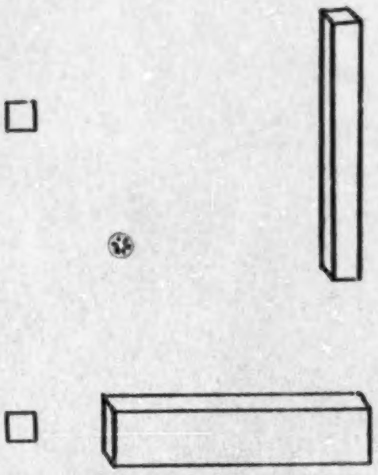

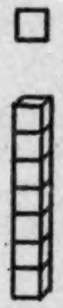

II. VERBAL RESPONSES

1.

____ push it down less
____ push it down the same amount
____ push it down more

2.

____ push it down less
____ push it down the same amount
____ push it down more

3.

____ cover fewer spaces
____ cover as many spaces
____ cover more spaces

4.

____ weaker
____ as strong
____ stronger

5.

____ applied to fewer spaces
____ applied to as many spaces
____ applied to more spaces

6.

____ 2 spaces
____ 3 spaces
____ 4 spaces
____ 6 spaces
____ 12 spaces

7.

____ 2 spaces
____ 3 spaces
____ 4 spaces
____ 6 spaces
____ 12 spaces

8.

____ standing on end
____ lying down

9.

____ 1 block
____ 2 blocks
____ 3 blocks
____ 4 blocks
____ 6 blocks

10.

____ one block on top of the first and two on top of each other next to it
____ three blocks on top of the first
____ three blocks in a row alongside the first
____ one block on top of the first and one on either side
____ two blocks on top and one on the side

11.

____ standing on end
____ lying flat on its side

12.

____ small side down
____ large side down

13.

____ all the blocks in a pile
____ all the blocks in a row
____ 4 in a row and 3 on top

APPENDIX C

CRITERION ACHIEVEMENT TEST FOR LESSON ON PRESSURE

Part 1

Answer the following questions by filling in the blanks. When the blanks are filled in, they will make complete and correct sentences.

1. An object always applies a downward force to the surface on which it is resting.
   A. When the object is placed in different positions, it applies ______________________________.
   B. When the object is in different positions, the pressure it produces depends on ______________________________.
2. Two boxes apply different amounts of downward force if ____________________.
3. Box A and box B both weigh 150 lbs. Box A is twice as big as box B. Box A produces less pressure because ______________________________.
4. If the amount of force applied remains the same, pressure will change if ______________________________.
5. There is a pressure of 400 lbs. per square inch on a bridge. This tells us that ______________________________.
6. A. A man wearing snow shoes walks on paper held three feet above the floor. The paper does not tear because ______________________________.
   B. The same man wearing ordinary shoes walks on the paper and the paper does tear because ______________________________.
7. A. How can we find out how much downward force a pole applies to the ground? ____________________.
   B. What else would we need to know to find out how much pressure the pole produces on the ground? ____________________.
   C. How would you compute the pressure? ____________________.
8. If you fall into quicksand, the best thing you can do not to sink into the quicksand, is to lie on your back. Explain why. ____________________.
9. A cement block weighing 150 lbs. is placed on the roof of a car. The bottom of the block has an area of 50 square inches.
   A. The total force applied by the block is ____________________.
   B. The total force is applied to an area of ____________________.
   C. The pressure is ______________________________.

10. If the area remains the same, any change in the amount of pressure on the area depends on ____.

Part 2

Put an X next to the best answer in each of the following questions.

1. Twelve heavy boxes have to be stored in a room with a weak floor. In order to produce the lowest pressure possible on the floor, it would be best to store the boxes

_____ one on top of each other.
_____ in 2 columns.
_____ in 3 columns.
_____ in 6 columns.
_____ separately in different parts of the room.

2. The man most likely to sink into deep snow is the man who

_____ sits down.
_____ lies down.
_____ stands on one foot.
_____ stands on two feet.
_____ balances himself on one finger.

3. The amount of downward force applied by an object depends on the

_____ size of the object.
_____ shape of the object.
_____ position of the object.
_____ weight of the object.
_____ area the object covers.

4. Water in a large tank weighs 120 lbs. The bottom of the tank has an area of 40 square inches.

A. The total force applied to the bottom is

_____ 3 lbs.
_____ 40 lbs.
_____ 80 lbs.
_____ 120 lbs.
_____ 160 lbs.

B. The pressure on the bottom of the tank is

_____ 3 lbs./sq. inch.
_____ 40 lbs./sq. inch.
_____ 80 lbs./sq. inch.
_____ 120 lbs./sq. inch.
_____ 160 lbs./sq. inch.

Study No. 2

APPENDIX D

ADDITIONAL RESULTS

Table 1

Analysis of Variance
for the Matching of Treatment Groups by IQ

	Sums of Squares	df	Mean Square	F
Order of Presentation	2.72	1	2.72	.08
Mode of Response	0	1	0	0
Order x Mode of Response	16.06	1	16.06	.46
Within	2391.22	68	35.16	

Table 2

Analysis of Variance
for the Matching of Treatment Groups by Work Rate

	Sums of Squares	df	Mean Square	F
A (IQ)	401.39	1	401.39	23.65***
B (Mode of Response)	.50	1	.50	.03
C (Order of Presentation)	.89	1	.89	.05
AB	.22	1	.22	.01
AC	16.05	1	16.05	.94
BC	.50	1	.50	.03
ABC	.23	1	.23	.01
Within	1086.22	64	16.97	

***significance at the .1% level

Table 3

Analysis of Variance for the Matching of Treatment Groups by Pretest

	Sums of Squares	df	Mean Square	F
A (IQ)	21.12	1	21.12	.43
B (Mode of Response)	23.35	1	23.35	.47
C (Order of Presentation)	30.68	1	.68	.62
AB	183.68	1	183.68	3.72
AC	1.69	1	1.69	.03
BC	66.12	1	66.12	1.34
ABC	36.12	1	36.12	.73
Within	3157.56	64	49.34	

Table 4

Analysis of Variance Comparing "Time to Complete" Scores for Groups Differing in Mode of Response

	Sums of Squares	df	Mean Square	F
A (IQ)	249.39	1	249.39	12.90**
B (Mode of Response)	112.50	1	112.50	5.82*
C (Order of Presentation)	72.00	1	72.00	3.72
AB	1.39	1	1.39	.07
AC	43.55	1	43.55	2.25
BC	50.00	1	50.00	2.58
ABC	.89	1	.89	.02
Within	1237.78	64	19.34	

****significance at the 1% level; *significance at the 5% level**

Table 5

Analysis of Variance of "Time to Complete" Scores for Pictorial and Verbal Response Groups (Visual/Verbal Order of Presentation Only)

	Sums of Squares	df	Mean Square	F
IQ	42.25	1	42.25	2.08
Mode of Response	156.25	1	156.25	7.69**
IQ x Mode of Response	.03	1	.03	.001
Within	650.22	32	20.32	

****significance at the 1% level**

Table 6

Analysis of Variance Comparing Immediate Posttest Scores for Pictorial and Verbal Response Groups (Visual/Verbal Order of Presentation Only)

	Sums of Squares	df	Mean Square	F
IQ	294.69	1	294.69	7.19*
Mode of Response	220.03	1	220.03	5.37*
IQ x Mode of Response	20.25	1	20.25	.49
Within	1311.78	32	40.99	

***significance at the 5% level**

Table 7

Analysis of Variance Comparing Delayed Test Scores for Pictorial and Verbal Response Groups (Visual/Verbal Order of Presentation Only)

	Sums of Squares	df	Mean Square	F
IQ	592.12	1	592.12	10.60**
Mode of Response	25.00	1	25.00	.45
IQ x Mode of Response	336.11	1	336.11	6.02*
Within	1787.33	32	55.85	

**significance at the 1% level; *significance at the 5% level

Table 8

Analysis of Variance of "Time to Complete" Scores for Visual/Verbal and Verbal/Visual Orders of Presentation (Pictorial Response Group Only)

	Sums of Squares	df	Mean Square	F
IQ	144.00	1	144.00	6.10*
Order of Presentation	121.00	1	121.00	5.12*
IQ x Order	28.44	1	28.44	1.20
Within	755.56	32	23.61	

*significance at the 5% level